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THE BOLL WEEVIL PROBLEM AND RESEARCH AND FACILITY NEEDS TO MEET  
THE PROBLEM

A Report of the Findings  
and  
A Detailed Supplemental Statement

Prepared By  
  
The Working Group on  
Boll Weevil Research Programs

appointed by  
  
The Office of the Secretary,  
United States Department of Agriculture

in response to  
  
Congressional Requests for a Report  
on the Boll Weevil Problem and  
Proposals for Meeting this Problem

December 30, 1958

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Report

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A REPORT ON THE BOLL WEEVIL PROBLEM AND RESEARCH AND FACILITY NEEDS TO  
MEET THE PROBLEM

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A REPORT ON THE PROGRESS OF THE WORK OF THE BOARD OF TRADE AND COMMERCE FOR THE YEAR 1900

AND THE STATE OF THE TRADE AND COMMERCE OF THE UNITED KINGDOM

BY THE SECRETARY OF STATE FOR COMMERCE

THE REPORT OF THE BOARD OF TRADE AND COMMERCE FOR THE YEAR 1900, AND THE STATE OF THE TRADE AND COMMERCE OF THE UNITED KINGDOM, IS HEREBY FORWARDED TO THE HOUSE OF COMMONS.

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## AUTHORIZATION AND PROCEDURE FOR MAKING THE BOLL WEEVIL STUDY

In the Agricultural Appropriations Reports for Fiscal Year 1959, both the House and Senate committees requested the Secretary of Agriculture to review the boll weevil problem and submit to the next appropriations committees a report on research and facility needs to meet this problem.

In order to obtain information on which to prepare a report on this major problem of the cotton industry, the Office of the Secretary appointed a working group to study the problem and (1) develop information on current research programs devoted to boll weevil investigations by State, Federal, and private industry; (2) determine the needs for an over-all comprehensive research program; and (3) determine broad areas of research which would be appropriate for federal attention and support in an effort to help meet the over-all needs. Members of the working group were: H. G. Johnston, National Cotton Council, representing the cotton industry; E. R. McGovran, Experiment Station Division, Agricultural Research Service, representing the State Agricultural Experiment Stations; and E. F. Knipling (Chairman), Entomology Research Division, Agricultural Research Service, representing the Department of Agriculture. C. R. Parencia, of the Entomology Research Division, served as Secretary of the working group.

In developing the information requested, the working group consulted entomologists, chemists, plant specialists, engineers, economists, and other scientists concerned with boll weevil research and control. A total of 17 conferences were held with state, federal and industry groups involving a total of 158 individuals. The agencies and individuals contacted are listed in the supplemental statement on current boll weevil research and facility needs which is attached to this report.

The information and suggestions obtained through conferences and consultations with the many research groups and individuals form the basis for this report on the boll weevil problems and the needs for research to meet the problem. In view of the great amount of valuable information obtained by the working group in consultation with the many individuals of the cotton industry, scientists, and agricultural administrators, an attached supplemental statement has been prepared which presents in more detail the findings of the working group.

## THE BOLL WEEVIL PROBLEM AND ITS SIGNIFICANCE TO THE COTTON INDUSTRY

Cotton industry leaders have repeatedly emphasized the fact that the economic survival of the industry depends upon adequate support for research necessary to strengthen cotton's ability to compete for markets. Scientists and industry leaders are agreed that the boll weevil clearly represents one of the most destructive and costly problems confronting the cotton industry, and therefore, is one of cotton's major problems urgently needing research support.



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The cotton industry, perhaps like no other segment of American agriculture, has been confronted with a major competitor, the synthetic fiber industry, which literally emerged from chemical research laboratories. This competitor has steadily penetrated markets, which historically belonged to American cotton producers, by exploiting an overwhelming advantage in the amount of research resources at its disposal for improving product quality and reducing production costs.

The magnitude of cotton's handicap is indicated by the fact that the combined budgets for synthetic fiber research by ten leading producers totals approximately \$75 million annually; in contrast, cotton research expenditures from all sources amount to only a little more than \$16 million annually.

The persistence and magnitude of the boll weevil problem, in a very important sense, reflects this general deficit in the research effort for cotton. The current research effort simply is not big enough to deal decisively with old, but constantly changing, problems and at the same time press forward with a vigorous program capable of anticipating new problems and heading them off before they become widespread and chronic.

#### The Boll Weevil Problem

The area infested by the boll weevil includes about 80 percent of the total cotton acreage in the United States, and about 95 percent of all cotton producers are involved. The boll weevil entered the United States from Mexico through south Texas about 65 years ago and soon spread eastward across the Cotton Belt to the Atlantic Coast. During the past few years it has been spreading westward along the Rio Grande Valley at an alarming rate. This situation poses a definite threat to cotton producers in the far west.

For the past 50 years the boll weevil has caused an estimated average annual loss to yield alone amounting to \$200 million or more with maximum losses up to \$900 million. For the six year period, 1949-1954, the average annual loss, based upon USDA estimates, was more than \$350 million. During that same period the average annual federal appropriation for boll weevil research, plus that portion of federal grants to states spent for boll weevil research amounted to \$73,385. This combined total was only .02 of one percent of the \$350 million annual loss suffered by cotton producers.

More than three-fourths of all insect losses to cotton in the United States are caused by the boll weevil, and cotton cannot be profitably grown in most areas where it occurs without adequate control measures. Additional losses including the cost of control and damage to cotton quality add many millions of dollars each year to the cost of cotton production.



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The full potential of improved production technologies have not been realized because of the boll weevil. Mechanization, irrigation, increased fertilization, and other practices have increased production efficiencies and held down the per pound cost of producing cotton. But, at the same time these practices have intensified the boll weevil problem.

Irrigation and increased fertilization have not only stimulated plant growth and fruiting but have extended the growing period later in the season. Such practices have virtually eliminated the effect of hot, dry weather, one of the most effective of all natural controls for the boll weevil, and have made conditions far more favorable for its rapid development. This means a potentially heavy population during the cotton fruiting period, increased costs for control ranging up to \$45 per acre and more during some seasons, and an extended population build-up in the fall.

The USDA Cotton Insect Laboratory at Tallulah, Louisiana, has compiled consecutive annual records of hibernating weevils from woods trash examinations since 1936. These records show that since the big expansion of new technologies in cotton production started, about 1945, there has been an 85 percent increase in the average number of live weevils hibernating in the fall—but, there has been an even greater increase of 147 percent in the average number of surviving weevils in the spring during the same period (1946-1955). Several factors may be responsible for this tremendous increase in the number of boll weevils emerging from hibernation in the spring, but, the most important one is changing practices in cotton production.

To successfully cope with this increasing population of weevils, the average annual use of insecticides expanded by millions of pounds. But, the expanded use of insecticides soon brought into sharp focus several serious complicating factors. By far the most disturbing of these factors was the development of resistance to chlorinated hydrocarbon insecticides by the boll weevil. In 1955, it was found that in some areas weevils had developed a pronounced resistance to five insecticides which had previously been the most effective and the most commonly used for their control. Resistant weevils have since been found in localized areas of five states from Texas to South Carolina and have been suspected in two others.

Fortunately, other chemicals are currently available that will control boll weevils and, no doubt, others can be developed. But, we have no assurance that weevils will not also develop resistance to them. Actually, there is some real solid evidence that they will.



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It is now quite clear that the future of conventional chemical control for boll weevils is seriously threatened--a threat that could prove disastrous to the cotton industry. The cotton producer is now wholly dependent upon conventional insecticides for boll weevil control. There is no other satisfactory method available and none in sight for the near future.

### New Approaches Needed for Boll Weevil Control

This study has clearly revealed that an adequate, comprehensive research program is urgently needed for boll weevil control. Among other things, more knowledge must be gained regarding the basic principles of insect physiology--how various chemicals kill boll weevils--what makes a resistant boll weevil resistant--how to avoid or counteract whatever mechanism the weevil has been able to develop that enables it to evade the toxic action of insecticides. A backlog of fundamental information must be developed upon which new approaches to boll weevil control can be based--approaches that are not wholly dependent upon conventional insecticides. To achieve these objectives it is necessary to intensify research on the insect itself and to call upon other research disciplines for assistance in the development of knowledge in certain phases of chemistry, plant science, soil science, and engineering that have a direct bearing upon the problem of boll weevil control.

### CURRENT RESEARCH ON THE BOLL WEEVIL PROBLEM

The findings of the working group on boll weevil research obtained from representatives in State Agricultural Experiment Stations and in the Agricultural Research Service showed that a total of 41 scientist man-years, 23 State and 18 ARS, are being devoted to boll weevil research. A brief discussion of current State and ARS effort in various areas of research follows:

#### Chemical Control

A high percentage, slightly less than 50 percent of the total effort, is expended on chemical control research with a total of 20.5 scientist man-years being devoted to it. Such research is receiving major emphasis because insecticides at present are the only means of effective control.

Considerable effort is being expended in laboratory, cage, and field evaluations of new insecticides of the conventional type, those applied to plants as dusts and sprays. In several states studies are made to determine whether and where boll weevil resistance to the chlorinated hydrocarbon insecticides is occurring. Laboratory studies are being made of resistance in successive generations of resistant and susceptible weevil strains reared in field cages and on artificial media.



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Basic work has recently been initiated through a team approach of an insect physiologist and a plant physiologist to study ways in which current systemic insecticides may be made effective for boll weevil control by increasing uptake of the materials by plants and by inducing their translocation to new plant growth and fruiting forms. Such work has also been started to study chemically induced resistance in the cotton plant to the boll weevil with materials that may not in themselves be toxic to the insect.

Preliminary work is underway in several states for the purpose of developing techniques for measuring attractancy of the boll weevil to the cotton plant and to various chemicals. Studies of comparative control obtained with single, multiple, and boom jet nozzles and of droplet sizes and deposits delivered by them are underway with agricultural engineers working on a part time basis with entomologists.

#### Basic Physiology and Nutrition

A total of 6.6 scientist man-years are being devoted to this area of research. An intensive study of nutritional requirements of the boll weevil is in progress, and techniques are being developed for mass rearing of the insect. Basic studies on the mechanisms of insecticide resistance in the boll weevil are in progress.

#### Biology and Ecology

A total of 6.4 scientist man-years is being devoted to biological and ecological studies with much of this effort being directed toward the determination of the number of weevils entering hibernation quarters in the fall and subsequent survival in the spring in various localities. The incidence of diapause in certain fields is being determined throughout the growing season, inspections are made to determine when weevils begin to enter hibernation quarters, and factors which influence diapause are being studied. Studies of seasonal movement and of the habits of the boll weevil which involve observations of movement, courses of action, and responses to various stimuli are underway.

#### Breeding Cotton for Boll Weevil Resistance

The effort expended in this area of research total 2.8 scientist man-years. Work in most instances is devoted to evaluating differences in degree of boll weevil infestation in different cotton species, or in breeding blocks maintained at Agricultural Experiment Stations. However, a breeder is incorporating several known promising resistant characters such as hairiness, red color and the absence of glands into a single line of cotton. A search for resistance under a heavy boll weevil infestation is also being made by an entomologist and a breeder in several hundred breeding lines, crosses and species.



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### Biological Control

Only a total of 0.9 scientist man-years is being expended in this area of research. Parasite studies are usually incidental to the rearing of weevils for other work. Limited studies are being conducted in cages to determine whether a parasitic nematode will destroy boll weevils when applied to woods trash in which they are hibernating. The effects of a native nematode on the reproductive capacity of infested females are being studied.

### Cultural Control

A total of 0.8 scientist man-year is being expended in limited studies of the effects of such practices as early stalk destruction, and the use of defoliants, dessicants and insecticides on weevil populations entering hibernation quarters and subsequent survival to infest the next year's crop.

### Economics and Cost Analysis of Boll Weevil Control

A total of 1.6 scientist man-years is being devoted to this study with this research being primarily an incidental evaluation by entomologists of the cost of control and profits derived therefrom although comparative values of different control program approaches is receiving some attention.

### Better Techniques For Determining Boll Weevil Infestations and Other Research

A total of 1.55 scientist man-years are involved in activities which are not included in areas of research previously discussed. These activities involve studies on the effect of boll weevil control measures on beneficial and injurious insects, on the development of better techniques in determining boll weevil infestations, and on improvement of survey methods.

### FINDINGS ON RESEARCH NEEDS FOR AN OVER-ALL PROGRAM ON THE BOLL WEEVIL PROBLEM

The findings of the Working Group showed that in meeting the requirements for a comprehensive research program on the boll weevil problem, the States, Federal Government and private industry must share responsibilities for the development and execution of an overall program.



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The study undertaken by the working group, involved consultations with many leading scientists representing various disciplines in States and Federal research institutions concerned with the boll weevil problem and with representatives of the cotton industry. Many excellent research proposals were offered that could contribute to the solution of the problem. The research proposals included important problems that are primarily of local significance as well as problems of broader significance which were regarded as appropriate for federal attention and support.

The over-all need for research to meet the boll weevil problem as determined by this study is briefly stated in this portion of the report and is discussed in more detail in the supplemental statement attached. The proposed federal program of research discussed in the next section of this report outlines more specifically the areas of research deemed appropriate for federal attention and support, including requirements for facilities. However, the proposed federal program does not provide for investigations on many important lines of research that were suggested. The state agricultural experiment stations may wish to consider the information obtained in this study which is discussed in considerable detail in the supplemental statement as a basis for State programs to also help meet the need for a more comprehensive program of research.

In the discussions of research needs with personnel of the USDA, the State stations, and with industry, there was general agreement that emphasis should be placed on new approaches to a solution of the boll weevil problem. It was also generally agreed that a substantial part of the effort should consist of basic research to develop new information useful in current applied research programs as well as to provide new leads for a better long range solution to the boll weevil problem. In the conduct of basic research there was particular interest in concentrating on certain strategic basic research that will have a direct bearing on the solution of current practical control problems as well as those which are likely to be encountered in the future. The need for strengthening research on certain applied aspects was also emphasized by many of those consulted. The importance of both basic and applied research is fully realized by the working group. Necessary information must be obtained to meet both the short range needs and long range solution of the boll weevil problem.

#### Chemical Control

At the present time, chemical control is the only satisfactory means of dealing with the boll weevil problem. The field evaluation of conventional insecticides developed largely by industry is an activity which is carried on by entomologists in all areas where the boll weevil is a major pest. It is the basis for making the annual insecticide recommendation for boll weevil control. This line of



research needs to be continued and expanded in practically all states if larger areas are used in field studies or additional promising new materials become available for field evaluation.

It was the consensus of opinion of the many individuals consulted that a search for new chemical control agents of various kinds needs adequate attention in an expanded research program. Such a program should include the search for new conventional insecticides, systemic insecticides, attractants and repellants. A concerted effort on new chemicals of the types mentioned would require the cooperation of entomologists, chemists, plant physiologists and soil technologists. The scientists should study chemical structure as related to biological activity. They should work closely with the chemical industry in the procurement of various types of materials for tests that are most likely to be useful for boll weevil control. They should, also, work closely with the chemical industry in the further development of materials which are likely to be used as practical insecticides, attractants or repellants. It was the feeling of the people interviewed by the working group that this would be the proper research procedure to follow in the selection and procurement of candidate chemicals for boll weevil control and that a research program of this nature should receive primary attention in an expanded program. Information obtained in such research would be made available to all entomologists for consideration in the planning of more advanced tests. Residues remaining on or in the cotton plant or in cotton seed must be determined as a part of the over-all effort before final recommendations of any new chemical control agent are made.

In appraising the potential value of chemicals for controlling the boll weevil the first step is to evaluate candidate insecticides, repellents, or attractants in the laboratory. This is usually the most rapid and least expensive way to select the most promising materials. Entomologists adequately provided with laboratory and greenhouse facilities are required for such research.

After the selection of promising materials in the laboratory, it has been the practice to conduct small scale field plot tests for further evaluation. The technique of using large field cages in lieu of small field plots to select the materials worthy of field evaluation appears to have considerable promise in speeding up the development of new chemicals. Entomologists with adequate laboratory and field cage facilities are needed for this work and they should be assisted by agricultural engineers in the design of better cages for such work. It seems desirable to develop this technique. Research on the evaluation of new promising chemicals for practical use needs to be carried forward in various areas in the boll weevil belt.



The development of resistance of the boll weevil to insecticides appears to be the major obstacle to the use of the most economical insecticides currently available and it may become so in the future for other insecticides now available. The occurrence and location of resistance should be determined in every area where the growers are having difficulty in obtaining adequate control with recommended insecticides. Such research requires the services of entomologists and adequate laboratory facilities with personnel to make field observations and to collect insects for more critical studies in the laboratory. Seasonal changes in resistance also need to be studied. Perhaps the best approach to a solution of the resistance problem in the boll weevil is a study of the physiological mechanisms involved. This is a very important field of research that might require studies on a wide range of compounds. Services of insect physiologists and biochemists with adequate laboratory facilities are required for such basic studies.

A systemic insecticide which could be applied to cotton seeds and would then protect the young cotton plant and its squares for 10 weeks from boll weevil attack, without leaving a harmful residue at harvest, is generally regarded as the ideal method of chemical control. There are currently available promising systemic insecticides for a wide range of insects and others are in preliminary stages of development. These need to be tested in various areas where boll weevils occur and under the many conditions encountered in the production of cotton. The services of field entomologists are needed for the applied phases of such study and insect physiologists, chemists, plant physiologists and soil scientists for both basic and applied studies.

Attractants and repellents for the boll weevil have received comparatively little attention, mainly because of the difficulty in evaluating the responses of these insects under laboratory conditions. However, it was generally agreed by those consulted that research in these areas should offer excellent possibilities for boll weevil control. For example effective attractants may be incorporated with insecticides as a bait spray or as a dust. Research on this approach would require the services of entomologists and chemists working as a team on both basic and applied aspects of the problem.

#### Physiology, Nutrition and Morphology

Study of the physiology of the sense organs, reproduction, diapause, insect growth hormones, and other enzyme systems and other physiological activities in the boll weevil offer real promise of revealing possible leads for discovering new approaches to boll weevil control. This research would require the services of insect physiologists and biochemists. The nutrition of the boll weevil is important from the standpoint of developing an artificial medium for rearing the insect in large numbers in the laboratory and determining the essential nutrients required.



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Some of these essential nutrients may be very attractive to the boll weevil and might be useful in bait sprays. Insect nutritionists have made substantial progress and further research is indicated to develop nutritional media for various purposes. Knowledge of the morphology of the sense organs, the reproductive organs and various other organs and systems in the boll weevil would be most helpful as background material for studying the physiology of these systems. Insect morphologists would be needed for this research.

#### Hibernation, Intensity of Infestation and Spread of the Boll Weevil

It was pointed out to the working group on a number of occasions that there was considerable opportunity for boll weevil control in the destruction of hibernating weevils if effective methods could be developed. This included preventing the build-up of the population of hibernating weevils in the fall either by mechanical or chemical methods, the destruction of the weevils in hibernation, either by chemical or biological means, and the killing of the weevils as they emerge from hibernation in the spring. Studies of this nature by entomologists and other scientists would be required in several areas because of variations in the environment, different planting dates, variations in fruiting periods of cotton, and differences in habits of the insect.

The level of infestation of boll weevil in cotton fields is of major importance in planning a control program. Entomologists need to study better methods for determining levels of boll weevil infestation and weevil movements from hibernation to cotton and from one location to another in and between cotton fields. Also, entomologists and plant physiologists need to obtain more information on the effect of climate and the stage of plant growth on the activities of the boll weevil.

The boll weevil has spread westward in recent years into the Presidio area of Texas. This may represent a threat to cotton growing areas in the more western states of New Mexico, Arizona and California. Studies should be made by entomologists in the area to determine, if possible, the reasons for and how to prevent further spread. The boll weevil is reported to be surviving in larger numbers in the northern edge of the cotton belt than formerly. Entomologists and possibly a geneticist might well study the boll weevils in these areas to determine if they represent physiological races that have become adapted to new environments.

#### Breeding Cotton for Resistance to Boll Weevil Attack

This is a long-range research program but one which almost everyone interviewed felt should be undertaken on a larger scale than at present and pushed vigorously in the future. Research on this problem will require participation of scientists in several cotton growing areas. Research should cover the evaluation of all species of cotton for all types of



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resistance to the boll weevil. Tolerance to weevil damage as well as adverse effects on the growth and survival of larvae or pupae and on the reproductive capacity of the insect should be evaluated. The combining of the best resistant characteristics found into one commercial variety of cotton would be the ultimate objective. The evaluation for degrees of resistance of all breeding material now in use and of all new varieties of cotton that are offered to the growers are other important phases of this investigation. This research would require entomologists who would work closely with agronomists and geneticists on both basic and applied phases of the problem.

An interesting phase of related research which has been started is the determination of the effect of boll weevil feeding and oviposition on the shedding of cotton squares. Knowledge of insect and plant physiology is needed for this work.

### Biological Control

There was wide variation in the opinion of various scientists in regard to the value of biological control of the boll weevil. In general, there seemed to be interest in a further search for parasites, predators and diseases of the boll weevil. This would include a search for those organisms both in the United States and in the native home of the boll weevil in Central America and southern Mexico. A new approach suggested for the use of parasites and predators for boll weevil control was to mass produce these in the laboratory and release them in overpowering numbers in cotton fields. Entomologists with adequate laboratory and field facilities would be needed for this research. In regard to disease organisms; fungi, bacteria, protozoa, viruses, and nematodes, all offer possibilities. The services of insect pathologists would be required for this research.

Insecticide treatments for boll weevil control may lead to development of other insect infestations that damage cotton. It is generally recognized that many parasites and predators of other cotton insects are killed by insecticide treatments for the boll weevil. A study of the effects of boll weevil control with insecticides on the parasites of other cotton insect pests is essential. Research on the effects of insecticides on honey bees and other pollinators is also an essential phase of investigation in connection with the selection of chemical control agents. Such investigations require the services of entomologists familiar with parasites and predators and other beneficial insects working in different locations to adequately determine the complex of host parasite relationships that exist in various areas.

### Destruction of Weevils in Squares on the Ground

In the early stages of fruiting of the cotton plant the destruction of weevils in the squares on the ground appears to be feasible. If done



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efficiently this would practically eliminate the first generation of weevils and contribute to a much lower infestation later in the season. Agricultural engineers consulted indicated to the working group that a machine could probably be developed that would pick up the squares off the ground under small cotton for about the same or possibly less cost per acre than an application of insecticide. Research on this approach would require agricultural engineers to develop the equipment and entomologists to evaluate the equipment and method as a practical control measure. There is also the possibility of using insecticides to destroy the weevil in squares on the ground. Such treatment might be applied in combination with herbicides. The evaluation of insecticides for this purpose in connection with the over-all development of chemicals for boll weevil control would be necessary under a wide range of conditions in the boll weevil belt. Flame cultivation might also be considered as a means of killing weevils in the squares, if the heat could be sufficiently increased economically and without injury to cotton.

#### Economics and Cost Analysis of Boll Weevil Control

Much interest was expressed in research to obtain more exact information on the cost of boll weevil control and the benefit derived from various control practices. Information on the best time to start and stop applying insecticides, the value of applying insecticides at different boll weevil infestation levels, and similar problems is needed. Research of this type would need the services of agricultural economists working with entomologists.

#### Effect of Boll Weevil Injury on Cotton Bolls and Other Research

In instances where there is a high infestation of boll weevil and the cotton has stopped squaring, many of the bolls may be damaged. Entomologists need to conduct research to determine the effect of this boll damage by boll weevil on the yield and quality of cotton produced from damaged bolls. Also, through joint effort of entomologists and plant pathologists, information is needed to determine the effect of boll weevil damage on boll rot in relation to weather and other conditions.

Another line of research requiring the cooperation of entomologists, agronomists and soil technologists, is needed to study the relationship of boll weevil damage to various soil and water management practices. Fertilization of cotton and irrigation create conditions which are generally favorable to development of boll weevil damage. A study of such relationships under various ecological conditions in the boll weevil belt should produce valuable information.

Development of suitable ground equipment for use in various areas is needed. Such research is needed in particular to develop machines to apply insecticides when the soil is muddy and to avoid damage in rank cotton. This problem would require a team approach by engineers and entomologists.



### Coordination of Research Programs

It appears desirable that some effort be made by states, USDA and industry to coordinate the over-all research program on the boll weevil to have it function with maximum efficiency. The primary objective would be to facilitate the exchange of current research results, plans, and ideas among the scientists actively engaged in boll weevil research. Such coordination of effort might be aided by the formation of a technical committee consisting of scientists representing the states, USDA and industry.



## FINDINGS ON NEEDS FOR A FEDERAL PROGRAM OF RESEARCH TO HELP MEET THE BOLL WEEVIL PROBLEM

A comprehensive research program to solve the boll weevil problem as previously stated will require the joint efforts of the industry, the State Agricultural Experiment Stations, and the U. S. Department of Agriculture.

Consultation with many scientists revealed the need for attention to important and potentially productive areas of research which are regarded appropriate for Federal support. These involve areas of research that are now receiving little or no attention, as well as certain lines of work now under investigation which are inadequately supported in scientific manpower, operating funds, and facilities.

Scientists and leaders in cotton production now realize that complete grower dependence on the use of conventional insecticide is not a satisfactory method of coping with the boll weevil problem because of insecticide resistance, mounting cost of chemical control, intensification of other cotton insect problems created by current insecticides, and public apprehension over the potential hazards of insecticides now in use. They advocate the initiation of a strong research program designed to develop for immediate use new kinds and new ways to employ chemicals for maximum efficiency, safety, and economy; and from a longer range viewpoint to develop methods of controlling the boll weevil which do not place complete reliance on chemicals.

Realizing the inadequacies of current control procedures, much of the effort of scientists now engaged on boll weevil research has been redirected to fundamental investigations pointing to new approaches to boll weevil control. However, only certain segments of the overall need can now be met with available research resources.

The nature and scope of an expanded federal research program suggested by this study, including additional facilities, are briefly outlined in this condensed report. A more detailed account of the nature of the research proposed is contained in the supplemental statement attached to this report.

### Additional Support for Federal Research in Progress

State and Federal scientists now engaged on boll weevil research were in unanimous agreement that in considering the need for additional Federal support, attention should first be given to the needs of the basic research now in progress. They point out that current Federal work programs are handicapped because of inadequate subprofessional assistants, operating funds, facilities and equipment.



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The working group has given careful consideration to this proposal and concurs in the view that every consideration be given to the needs for current scientists engaged in basic studies so that they can conduct their work with maximum efficiency.

It has been determined that in order to achieve the proper balance between scientists and supporting personnel and to provide adequate funds for operations will require the allocation of additional funds amounting to about one half the current annual budget for the stations at College Station, Texas, Baton Rouge, Louisiana, and Florence, South Carolina. In addition, there is an urgent need for greenhouse, headhouse, and outdoor insectary facilities at each location so that the work under way can proceed on a sounder and more efficient basis.

Additional support for the purposes stated would facilitate research at College Station on the nutritional requirements of the boll weevil, and on methods of rearing the insect in the laboratory. It would also expedite important basic research now under way on the translocation and mode of action of systemic insecticides in the cotton plant.

At Baton Rouge, Louisiana, the basic investigations on the nature and cause of insecticide resistance in the boll weevil and how to correct or avoid such resistance would be intensified.

At Florence, South Carolina, the additional support would facilitate studies on boll weevil migration from field to field and to and from hibernating areas. Information of this nature is essential in connection with proper timing of boll weevil treatments, and to minimize the number required for satisfactory control.

#### Establishment of a New Federal Boll Weevil Research Laboratory

To initiate a Federal research program on the various lines of investigation suggested by this study, the Federal and industry groups, favored the establishment in one location of a corps of research scientists, representing different disciplines, who would concentrate in a team approach on the various areas of research suggested that are regarded appropriate for Federal attention. They also favored the establishment of such laboratory at a Land Grant College because of the many advantages to basic research in such location. The state groups, in general, were not in agreement with the concentration of research in one location but urged that new work for the most part be undertaken at State Experiment Station locations conducting research along lines proposed for expansion.



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Careful consideration has been given by the working group to the views of the various groups. It has taken into consideration the nature of the research proposed and the scientific disciplines required to develop the research on problems of broad significance. On the basis of these considerations it is indicated that the proposed Federal research program, except for some strengthening of basic research in progress, would most effectively support the over-all effort if it were largely concentrated in one location in a well-equipped laboratory.

In considering the location for such work, State College, Mississippi, because of its central location in the boll weevil area and its proximity to the Mississippi Delta appears most desirable from an over-all standpoint.

#### Nature and Scope of a New Federal Research Program

Chemical Control - For the foreseeable future, the farmer must continue to rely on chemicals to meet the boll weevil problem. There was almost unanimous agreement, however, among the many scientists contacted that additional research on chemicals for boll weevil control should be directed primarily to the development of new approaches to chemical control, with emphasis on (1) systemics for seed, soil, or foliage treatment; (2) baits and other attractive substances; and (3) exploration of the possibilities of developing new chemicals such as growth regulating materials. Substantial progress in the development of better and more economical chemicals could make a major contribution to a solution of the boll weevil problem. For example, if a systemic chemical could be developed for seed treatment which would destroy or prevent normal development of the insect for a period of 10 weeks from the time of planting, such material would provide a satisfactory solution to control and might even lead to eradication of the pest.

It is generally recognized, however, that in view of the insecticide resistance problem, and the possible immediate need for substitute insecticides, the search for insecticides of the conventional type must also be given adequate attention.

It has been estimated that a well rounded Federal program of research on various approaches to chemical control to develop efficient, safe, and economical chemicals will require a team of specialists consisting of three entomologists, three chemists, one plant physiologist, and one soil scientist.



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The unit working on chemicals would serve as a corps of investigators to fully explore the potential value of all types of chemicals for boll weevil control such as systemics for adults or larvae, attractants, conventional insecticides for adult boll weevil or larvae and pupae in squares. It would serve as a clearing house for basic information on the nature and performance of such chemicals and thus contribute to the over-all effort of State, Federal, or industrial research laboratories primarily concerned with the practical development of chemicals for boll weevil control. This unit would also facilitate the work of other scientists engaged in basic studies on modes of action by preparing chemical compounds needed for investigations on the mode of action of chemicals. Another important function of the chemical unit would be to make such analyses as will be required to establish the nature and extent of residues that appear in cotton seed products when new chemicals are under development for practical control.

Development of Cotton Varieties Resistant to the Boll Weevil - It was the opinion of all scientists consulted that successful development of cotton varieties which are highly resistant to boll weevil attack would be the most desirable and most economical long range solution to the boll weevil problem.

A concerted research effort in this direction in which the States, Federal government, and seed industry would all cooperate, could lead to substantial progress, based on the successes that have been achieved by teams of entomologists and plant geneticists working on Hessian fly resistant wheats, European corn borer resistant corn, and spotted alfalfa aphid resistant alfalfa. Investigators in Arkansas and North Carolina who have recently initiated research on this approach to boll weevil control have obtained promising results in this line of research.

The Federal government is in a good position to actively participate in an over-all program of research, both basic and applied, on varietal resistance to the boll weevil. It has active cooperative work on various cotton improvement programs involving a number of other characteristics. It has access to species, varieties, and crosses in cottons of all kinds. It is estimated that the scientific staff on varietal resistance should consist of three entomologists, and two plant geneticists.

The scientists would cooperate with State and private cotton breeders in a search for boll weevil resistant germ plasm, including varieties of cotton which flower only in tropical areas. Facilities and personnel would be available for routine testing for boll weevil resistance in varieties submitted by Federal, State, and industry breeders who are engaged in over-all cotton improvement programs.



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A major breakthrough in finding highly resistant characters in cotton could provide the ideal solution to the boll weevil problem. Even a low level of resistance, in commercial and otherwise desirable varieties, would save the grower millions of dollars annually.

Basic Investigations on Insect and Plant Physiology and Ecology -

There is a general lack of information on many aspects of boll weevil development, behavior, ecology, and their relationships to the cotton plant. Both State and Federal research laboratories now have under way research on a number of fundamental problems which can be expected to provide much new information. However, in order to help guide the research on various new approaches to boll weevil control, much additional basic research in this area is needed. Certain studies on the biology, physiology, and ecology of the boll weevil can be conducted most advantageously by investigators in existing state laboratories. Certain other fundamental studies, however, would be appropriate in a Federal program, and a staff of two insect physiologists, one plant physiologist, and one ecologist is proposed for basic research on insect physiology, plant physiology, and ecology.

The group working as a team would concentrate on a study of the physiology of the boll weevil with particular emphasis on the growth regulating mechanisms and on ways of upsetting such mechanisms. The research would include investigations on the interrelationship of the insect's development and behavior and the physiological changes in the cotton plant. Investigations of the nature proposed on insect and plant physiology and on the insect behavior should provide basic information which would be especially useful in guiding research on the development of growth regulating chemicals, attractants, and systemics.

Biological Control - Most scientists consulted were firm in their views that in a comprehensive program of research on boll weevil control, the possibilities of developing ways to use biological agents should be given attention.

Lines of investigation proposed included work on parasites and predators, insect diseases, and on genetic approaches. A study of these aspects of biological control would require one insect pathologist, one entomologist, and one insect geneticist.

The insect pathologist would concentrate on naturally occurring diseases, including a search for such diseases in the native home of the boll weevil. Any disease organisms--bacteria, protozoa, nematode, virus, or fungi found to be pathogenic to the insect would be investigated. Promising materials would be cultured in sufficient quantity for large scale tests by Federal and State entomologists engaged in conducting field tests.



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Research on boll weevil parasites and predators would be concentrated on the development of boll weevil control through the production and mass releases of parasites or predators in cotton fields. Another important study would be to determine the effects of new boll weevil insecticides on beneficial insects for the purpose of selecting those which will create the least upset in the balance of natural beneficial insects in cotton fields.

The insect geneticist would investigate the possible use of sexually sterile males and other genetic methods for boll weevil control or eradication.

Supporting Research - There was unanimous agreement that an Agricultural Engineer should join the team of scientists to conduct research, both basic and applied, on the development of necessary equipment required for boll weevil control.

The need for research on the economics of boll weevil control was also generally recognized. An Agricultural Economist would work with the staff in the planning and in the execution of various field experiments on boll weevil control and concurrently make cost analysis of various control methods in such experiments.

Summary Listing of the Areas of Research and the Estimated Number of Senior Scientists Required for Each Area -

Areas of Research	Number of Scientists
Chemical control	8
Varietal resistance	5
Insect and plant physiology and ecology	4
Biological control	3
Supporting agricultural engineering research	1
Supporting agricultural economics research	1
Total senior scientists	22

Facility Requirements for a New Federal Laboratory

In order to carry out the program of research outlined, involving a staff of 22 scientists plus supporting personnel, it will be necessary to provide suitable laboratory and office space. In addition to the main laboratory installation, it will be necessary to provide adequate greenhouse, headhouse, and outdoor insectary facilities and land for the buildings and field plots.



Relationship of the Federal Research Program to Other  
Federal, State, and Industry Research Activities

It should be emphasized that the new program outlined which is regarded appropriate for Federal support represents only a part of the total need for research on the boll weevil. To provide the additional research needed for an over-all program as determined by this study, it is hoped that the states and industry will consider initiating additional research to help solve the problem.

In the conduct of the expanded Federal research program outlined, the indicated support for bolstering the current programs at College Station, Texas; Baton Rouge, Louisiana; and Florence, South Carolina; would contribute directly and immediately to the strengthening of cooperative work in progress.

The research program of the proposed new boll weevil laboratory should be closely coordinated with that of other Federal laboratories and close cooperation should be developed with the state and industry research groups in order to make maximum contributions to the over-all effort of meeting the boll weevil problem.



Administratively Confidential

A DETAILED SUPPLEMENTAL STATEMENT ON THE BOLL WEEVIL PROBLEM AND  
RESEARCH AND FACILITY NEEDS TO MEET THE PROBLEM

Prepared by

The Working Group on  
Boll Weevil Research Programs

December 30, 1958



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DETAILED SUPPLEMENTAL STATEMENT ON THE BOLL  
WEEVIL PROBLEM AND RESEARCH AND FACILITY NEEDS TO MEET THE PROBLEM

AUTHORIZATION AND PROCEDURE FOR MAKING BOLL WEEVIL STUDY

The Boll weevil, a foreign insect immigrant, has cost the cotton industry billions of dollars since late in the last century. In spite of past research efforts to solve this problem, this pest still represents a major cost to cotton producers in the infested areas--a cost that scientists in the cotton industry believe can be reduced or possibly eliminated entirely through a concerted program of research.

As the result of strong representation before Congress by the cotton industry for a program of research to adequately deal with the boll weevil problem, both the House and Senate Committees on agricultural appropriations for Fiscal Year 1959 provided additional funds to strengthen research and urged a further review to determine the needs for a program of research to meet the problem.

The House Committee on Agricultural Appropriations made the following request:

"The Secretary is urged to review this matter and recommend during his next appearance before this Committee concrete proposals for meeting this problem. For this purpose, an additional amount of \$25,000 should be allocated, from funds available for the coming year."

The Senate Committee on Appropriations express its concern over the boll weevil problem in the following language:

"(1) \$100,000 to accelerate research on the boll weevil, in addition to the House proposal. This insect has caused extensive damage to cotton for many years. Present control programs are costly and often ineffective. The Committee recommends this increase to immediately strengthen research efforts and to enable the Department to review the problems of the boll weevil. It is requested that following such review, a comprehensive research program be developed which will embody the proposed needs, including plans for necessary facilities, for research and experimental purposes."

Appointment of Study Group

In order to obtain information upon which to prepare a report to Congress, the Office of the Secretary, U. S. Department of Agriculture, appointed a working group to study this problem. The working group



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consisted of three members: Dr. E. F. Knipling, Entomology Research Division, representing the Agricultural Research Service; Dr. E. R. McGovran, State Experiment Stations Division, representing the State Experiment Stations; and Dr. H. G. Johnston, National Cotton Council of America, representing the cotton industry. Dr. Knipling was selected as chairman and Mr. C. R. Parencia, Entomology Research Division, served as secretary.

The working group was instructed to study the problem and (1) develop information on current research programs devoted to boll weevil investigations by State, Federal and private industry; (2) determine the needs for an over-all comprehensive research program; and (3) determine broad areas of research which would be appropriate for federal attention in an effort to help meet the over-all needs. This would include (a) specific areas of research needing federal attention, (b) estimates of the number of scientists in various disciplines required to carry out the investigations, (c) locations where work should be undertaken, and (d) need for additional facilities for each location.

#### Procedure for Making the Study

In the process of making the study, the working group held a total of 17 group conferences with 158 research workers, administrators of agricultural research programs and leaders in the cotton industry in order to obtain their views on the boll weevil problem and the type of research programs that will be required to meet the problem. The list of participants is given on Page      of the Supplemental Statement attached to the report.

The various federal, state and industry groups consulted are listed below:

#### Agricultural Research Service, U. S. Department of Agriculture

- Agricultural Engineering Research Division
- Crops Research Division
- Entomology Research Division
- Farm Economics Research Division
- Soil and Water Research Division

#### State Agricultural Experiment Stations

Conferences were held with researchers in 9 of the 12 states in which the boll weevil is a problem. These conferences included entomologists, chemists, plant physiologists, geneticists, engineers, and economists. In addition to state experiment station personnel, representatives of the same disciplines from ARS located at or in the vicinity of these stations also participated in the discussions.



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The stations visited were as follows:

Texas Agricultural Experiment Station, College Station, Texas.  
Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana.  
Delta Branch, Mississippi Agricultural Experiment Station,  
Stoneville, Mississippi.  
Alabama Agricultural Experiment Station, Auburn, Alabama.  
Georgia Agricultural Experiment Station, Experiment, Georgia.  
North Carolina Agricultural Experiment Station, Raleigh, North  
Carolina.  
Pee Dee Experiment Station of the South Carolina Agricultural  
Experiment Station, Florence, South Carolina.  
Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.  
Arkansas Agricultural Experiment Station, Fayetteville, Arkansas.

The Missouri, Tennessee, and Florida State Experiment Stations, in which States the boll weevil is of relatively minor importance, were contacted by correspondence and furnished information pertinent to this study.

#### Representatives of Industry

To represent industry from the Southwest, two prominent agricultural leaders and officials of the National Cotton Council, Mr. George C. Chance and Mr. Eugene Butler, were invited to participate in the group meeting with the Texas Agricultural Experiment Station held at College Station, Texas.

In the mid-South a conference was held with the research and production staffs of the Delta and Pine Land Company at Scott, Mississippi.

In the Southeast a conference was held with the research and production staffs of Coker's Pedigreed Seed Company at Hartsville, South Carolina.

To complete the contacts with the cotton industry a conference was held with certain representatives of the research staff of the National Cotton Council, Memphis, Tennessee.

#### Acknowledgements

The working group is indebted to the many individuals with the U. S. Department of Agriculture, the State Agricultural Experiment Stations and the Cotton Industry for their cooperation and assistance in making this study. In every conference the participants exhibited enthusiasm and interest in this study. The discussions were held in a spirit of informality and all participants presented their views freely with a spirit of optimism and whole hearted cooperation. Every conference yielded new information and new suggestions on which the working group



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could draw in preparing its report. The group considers it a privilege to have had the opportunity of consulting with the many dedicated research workers and their administrators in the State, industry and federal institutions who have an interest in and a responsibility for the advancement of the cotton industry.

#### THE BOLLWEEVIL PROBLEM AND ITS SIGNIFICANCE TO THE COTTON INDUSTRY

Cotton industry leaders have often emphasized the fact that the economic survival of the industry depends upon adequate support for research necessary to strengthen cotton's ability to compete for markets. Scientists and industry leaders are agreed that the boll weevil clearly represents one of the most destructive and costly problems confronting the cotton industry, and therefore, is one of cotton's major problems needing immediate research support.

The cotton industry, perhaps like no other segment of American agriculture, has been confronted with a major competitor--the synthetic fiber industry--which literally emerged from chemical research laboratories. And, this competitor has been able to steadily penetrate markets, which historically belonged to American cotton producers, by exploiting an overwhelming advantage in the amount of research resources at its disposal for improving product quality and lowering production costs.

#### Cotton's Handicap - \$16 Million Vs \$75 Million Annually

The magnitude of this handicap is indicated by the fact that the combined research budgets of ten leading synthetic fiber producers totals approximately \$75 million annually; in contrast, expenditures on cotton research from all sources amount to only a little more than \$16 million annually. The distribution of expenditures for cotton research in relation to synthetic fiber research is as follows:

Synthetic Fiber Research by Ten Leading Firms	\$75,000,000
All Cotton Research in the United States	
Private Industry	\$ 8,170,000
State Experiment Stations	2,764,000
U. S. Department of Agriculture	5,055,000
Other Institutions, Private Laboratories, etc.	<u>372,000</u>
Total	16,361,000

The persistence and magnitude of the boll weevil problem in a very important sense, reflects this general deficit in research efforts. The current research effort simply is not big enough to deal decisively with old, but constantly changing, problems and at the same time to press forward with a vigorous program capable of anticipating new problems and heading them off before they become widespread and chronic.



### The Boll Weevil Problem

The portion of the Cotton Belt infested by the boll weevil includes about 80 per cent of the total cotton acreage in the United States, and more than 95 per cent of all cotton growers are involved. The boll weevil entered the United States from Mexico through south Texas about 65 years ago and soon spread eastward across the Cotton Belt to the Atlantic Coast. During the past few years it has been spreading westward along the Rio Grande Valley at an alarming rate. This situation poses a definite threat to cotton growers in the far west.

#### Losses Due to Boll Weevil

For the past 50 years the boll weevil has caused an estimated average annual loss, due to reductions from full yield, of \$200 million or more with maximum losses amounting to \$900 million. For the six-year period, 1949-1954, the average annual loss, based upon USDA estimates, was more than \$350 million. During that same period the average annual federal appropriation for boll weevil research amounted to \$54,260 and that portion of federal grants to States spent for boll weevil research amounted to \$19,125 or a total of \$73,385 annually. This total amounted to only .02 of one per cent of the \$350 million annual loss suffered by cotton producers.

About 80 per cent of the total insect loss to cotton in the United States is caused by the boll weevil and cotton cannot be profitably grown in most areas where it occurs without adequate control measures. Additional losses including the cost of control and damage to cotton quality add millions of dollars each year to the cost of cotton production in the infested area.

#### Effect of Improved Practices on the Boll Weevil Problem

Improved technologies have been a vital factor in more efficient cotton production. But the full potential of these improvements have not been realized because of the boll weevil. Mechanization, increased fertilization, irrigation, and other practices have increased production efficiencies and held down the per pound cost of producing cotton. But at the same time these practices have increased the problems involved in boll weevil control.

It is common knowledge that boll weevils are more readily attracted to vigorous, succulent, rapidly fruiting cotton plants than to less thrifty ones. Irrigation and heavy fertilization have not only stimulated plant growth and fruiting, but have extended the growing period later in the season. Such practices have virtually eliminated the effect of hot, dry weather, one of the most effective of all natural controls for boll weevils, and have made conditions far more favorable for their rapid development. This means a potentially heavy population



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during the cotton fruiting period, increased costs for control ranging up to \$45 per acre or more during some seasons, and an extended population build-up in the fall.

There is ample evidence to prove that the boll weevil population potential has increased tremendously during recent years. The USDA Cotton Insect Laboratory at Tallulah, Louisiana, has compiled consecutive annual records of hibernating weevils from woods trash examinations in Madison Parish since 1936.

These records show that since the big expansion of new technology in cotton production started, about 1945, there has been an 85 per cent increase in the average number of live weevils hibernating in the fall-- but there has been an even greater increase of 147 per cent in the average number of live weevils in the spring during the same period (1946-1955). There is evidence to indicate that similar conditions exist in other areas of the Cotton Belt. Several factors may be responsible for this tremendous increase in the number of boll weevils emerging in the spring, but the most important one is changing practices in cotton production.

#### Resistance to Insecticides Intensifies Boll Weevil Problem

To successfully cope with this increasing boll weevil population, the average annual use of insecticides has expanded by millions of pounds. But the expanded use of insecticides soon brought into sharp focus several complicating factors. By far the most disturbing of these factors was the development of resistance to chlorinated hydrocarbon insecticides by the boll weevil. In 1955, it was found that in some areas weevils had developed a pronounced resistance to five insecticides which had previously been the most effective and the most commonly used for their control. Resistant weevils have since been found in localized areas of five States from Texas to South Carolina and have been suspected in two other States.

Fortunately, other chemicals are currently available that will control boll weevils and, no doubt, others can be developed. But we have no assurance that weevils will not also develop resistance to them. Actually, there is some pretty solid evidence that they eventually will.

It is now quite clear that the future of conventional chemical control for boll weevils is seriously threatened--a threat that could prove disastrous to the cotton industry.

#### New Approaches Needed for Boll Weevil Control

This study has clearly revealed that an adequate, comprehensive research program must be developed for boll weevil control. Among other things,



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more knowledge must be gained regarding the basic principles of insect physiology--how various chemicals kill insects--what makes a resistant boll weevil resistant--and how to counteract whatever mechanism the weevil has been able to develop that enables it to evade the toxic action of insecticides. A backlog of fundamental information must be developed upon which new approaches to boll weevil control can be developed--approaches that are not wholly dependent upon conventional insecticides. To achieve these objectives it is necessary to call upon other disciplines for assistance in the development of knowledge in certain phases of chemistry, plant science, soil science, and engineering that have a direct bearing upon the problem of boll weevil control.

#### CURRENT RESEARCH ON THE BOLL WEEVIL

A knowledge of current research activities is essential in appraising the over-all need for a comprehensive research program. Primary attention was given to research in progress by State Experiment Stations and the U. S. Department of Agriculture. It is recognized that members of industry, such as chemical and equipment manufacturers, and such organizations as the National Cotton Council support State and Agricultural Research Service (ARS) research in many important ways and conduct developmental research of their own on boll weevil control. However, no attempt has been made to evaluate industry's contributions to boll weevil research in terms of scientific man years.

Information obtained from representatives in State Agricultural Experiment Stations and in ARS indicated that a total of 41.15 scientist man years, 22.95 State and 18.2 ARS, are being devoted to boll weevil research. The research contributions of scientists in various disciplines, other than entomology, such as plant physiology, cotton breeding and agricultural engineering are included in determining the research effort in both State and ARS programs although these workers generally are contributing only part-time effort in applicable phases of the studies. The scientist man years being devoted to the boll weevil in various areas of research are shown in Table 1.



TABLE 1

Scientist Man Years Both State and Federal Devoted to Boll Weevil Research

State	Chemical : Control	Basic : Physiology & Nutrition	Biology : and Ecology	Breeding : Resistance	Biological : Control	Cultural & Mechanical : Control	Economics and Cost Analysis : of Control	Other : Research	Total : Man Years
Texas	State: 1.5 ARS: 3.65	— : 2.0	1.0 : 0.5	0.5 : —	— : —	— : 0.1	— : —	0.5 : —	3.5 : 6.25
La.	State: 1.0 ARS: 2.6	1.0 : 3.0	1.0 : 0.2	0.1 : —	— : —	— : 0.2	— : 0.1	— : —	3.1 : 6.1
Miss.	State: 1.5 ARS: 1.5	— : —	— : 0.5	0.25 : 0.25	— : 0.2	— : 0.2	0.25 : 0.2	0.25 : —	2.25 : 2.85
Ala.	State: 2.25 ARS: —	— : —	— : —	— : —	0.25 : —	— : —	0.25 : —	— : —	2.75 : —
Georgia	State: 1.0 ARS: —	— : —	0.05 : —	0.1 : —	— : —	— : —	— : —	— : —	1.15 : —
N. Car.	State: 0.5 ARS: —	— : —	— : —	0.25 : —	0.25 : —	— : —	0.25 : —	— : —	1.25 : —
S. Car.	State: 0.6 ARS: 2.05	0.1 : —	0.9 : 0.8	— : 0.05	— : 0.1	— : —	— : —	0.6 : —	2.2 : 3.0
Okla.	State: — ARS: —	0.5 : —	— : —	— : —	— : —	— : —	— : —	— : —	0.5 : —
Ark.	State: 1.35 ARS: —	— : —	1.35 : —	1.3 : —	0.1 : —	0.3 : —	0.3 : —	0.2 : —	4.9 : —
Mo.	State: — ARS: —	— : —	0.1 : —	— : —	— : —	— : —	— : —	— : —	0.1 : —
Tenn.	State: 1.0 ARS: —	— : —	— : —	— : —	— : —	— : —	0.25 : —	— : —	1.25 : —
Florida	State: — ARS: —	— : —	— : —	— : —	— : —	— : —	— : —	— : —	— : —

Total State:	10.7	1.6	4.4	2.5	0.6	0.3	1.3	1.55	22.95
Total ARS:	9.8	5.0	2.0	0.3	0.3	0.5	0.3	—	18.2

Combined Total:	20.5	6.6	6.4	2.8	0.9	0.8	1.6	1.55	41.15
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Activities in most of the research areas cannot be completely separated from others because most investigators are concerned with several phases of boll weevil research. However, estimates of the amount of time devoted to various lines of research were made to present as accurately as possible a report on current research activities. A discussion of current effort in various areas of research follows.

### Chemical Control

It was found that a high percentage, slightly less than 50 per cent, of the total effort is expended on chemical control research with a total of 20.5 senior scientist man years being devoted to research in this area. Such research is receiving major emphasis because insecticides at present are the only means of effective boll weevil control. Cotton growers are in need of more economical, more efficient and less hazardous insecticides for use in their control programs. The development of boll weevil resistance in some areas to the chlorinated hydrocarbon insecticides has complicated the problem since phosphate insecticides, which will give control of such resistant weevils, are generally expensive, and most of them are highly toxic to man. Although there is currently no indication of boll weevil resistance to the organic phosphate compounds, experiences with other insects indicate that there can be no assurance that weevils will not develop resistance to them.

### Conventional Insecticides

Laboratory and field cage evaluations of new insecticides of the conventional type, those applied to plants as dusts and sprays, are being made in cooperation with the States at ARS laboratories at College Station, Texas; Stoneville, Mississippi, and Florence, South Carolina, with such evaluations receiving more emphasis at College Station. Some work along this line is also in progress by state workers in Arkansas. Field evaluations of the efficacy of insecticides, with timing of applications receiving some consideration, are being made in all States in which the boll weevil occurs, with the exception of Oklahoma, Missouri, and Florida. The work in this area by the Experiment Stations of Texas, Louisiana, Mississippi, and South Carolina, are cooperative with ARS with most of the effort supported by ARS in the two latter States.

In Texas, Louisiana, Mississippi, Alabama, Georgia, North Carolina, and South Carolina, considerable effort is being expended in laboratory studies to determine whether resistance to the chlorinated hydrocarbon insecticides has developed in various localities, especially where cotton growers have experienced some difficulty in obtaining boll weevil control with them. In the ARS laboratory at Baton Rouge, studies are being made of resistance in successive generations of resistant and susceptible weevil strains reared in field cages. Topical applications of endrin, Guthion and a mixture of the two insecticides are made to individuals in each generation in an effort to determine how many generations are required for resistance to develop and how many generations may



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be required before reversion of resistance occurs. Survivors of the tests produce the next generation of the various strains. At the College Station ARS laboratory, similar studies with weevil strains reared on artificial media are in progress.

### Systemic Insecticides

Previous laboratory and field tests have shown that the systemic insecticides Thimet and Di-Syston, employed as cottonseed treatments, do not trans-locate in the cotton plant in sufficient quantities or for a long enough period of time to effect overwintered boll weevil control although they are effective against thrips, spider mites and cotton aphids for several weeks. Basic work has recently been initiated at the ARS laboratory in College Station through a team approach of an insect physiologist and a plant physiologist to study ways in which current systemic insecticides may be made effective for boll weevil control by increasing uptake of the materials by plants and by inducing their translocation to new plant growth and fruiting forms. Basic work, also, has been initiated at the ARS laboratory at Florence, South Carolina, to study chemically-induced resistance in the cotton plant to the boll weevil with materials that may not in themselves be toxic to the insect.

### Attractants

Preliminary work is under way by state workers at Auburn, Alabama; Fayetteville, Arkansas, and by ARS workers at Florence, South Carolina, in the development of techniques for measuring attractancy of the boll weevil to the cotton plant and chemicals.

### Methods of Application

Some work on insecticide application methods, with agricultural engineers working on a part-time basis with entomologists, is being done in Texas, Mississippi, and Arkansas. In Texas, this consists of studies of comparative control obtained with single, multiple, and boom jet nozzles and of droplet sizes and deposits delivered by them. Some work on modification of high clearance ground equipment for more effective spray applications of insecticides for control of the boll weevil and other cotton insects is also in progress in Mississippi and Arkansas.

### Effects of Insecticides on the Cotton Plant

Observations on the effects of various insecticides applied to cotton plants are being made by entomologists in field plot experiments conducted for the evaluation of their efficacy against the boll weevil. This includes observations on phytotoxicity and delay or acceleration of fruiting and maturity. The services of a plant physiologist are usually not available for these evaluations.



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### Basic Physiology and Nutrition

A total of 6.6 scientist man years are devoted to various types of studies classified as basic physiology and nutrition. This work is being done in Texas, Louisiana, and Oklahoma, in an effort to meet in part the recognized need for more basic knowledge of the boll weevil.

An intensive study of the nutritional requirements of the boll weevil is in progress at the ARS laboratory in College Station, Texas. The insect has been reared for many generations on a chemically defined diet but pollens or other plant extracts have to be added to it so that females reared on it will oviposit readily. Considerable progress is being made in the development of techniques for mass rearing of the insect. The mode of action of chemicals in the cotton plant through the use of radioactive Thimet is being studied.

Basic studies on the mechanisms of insecticide resistance in the boll weevil are being made at the Louisiana-ARS Baton Rouge laboratory. A study of the boll weevil physiology in relation to its aging process has been initiated to help explain variations in resistance of the boll weevil to insecticides at different times of the year.

In Oklahoma some work is under way to determine what causes squares to shed after weevils have fed on them. The possibility that saliva introduced through feeding may be responsible for a secondary disease infection is being investigated.

### Biology and Ecology

A total of 6.4 scientist man years is devoted to biological and ecological studies in Texas, Louisiana, Mississippi, Georgia, South Carolina, Arkansas, and Missouri. Much of this effort is directed toward the determination of the number of weevils entering hibernation quarters in the fall and subsequent survival in the spring through inspection of ground trash samples collected in the same locations in various localities. Survival studies under cage conditions are under way at several locations. These studies are supplemented by plant inspections in the field during early summer. In Texas and Mississippi, the incidence of diapause in populations in certain fields is being determined at intervals throughout the growing season, inspections of trash collected from nearby hibernation areas are made at regular intervals to determine when weevils begin to enter hibernation quarters, and factors which influence diapause under field conditions are being studied. Flight screen studies are in progress at several locations to determine when weevils leave hibernation quarters to enter cotton fields and to study seasonal movement. In Arkansas, studies are under way on the habits of the boll weevil which involve observations of movement, courses of action and responses to various stimuli.



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### Breeding Cotton for Boll Weevil Resistance

The effort expended in this area of research totaled 2.8 scientist man years in Arkansas, North Carolina, Mississippi, Texas, Louisiana, Georgia, and South Carolina. Most of this effort is supported by State funds. The work in the latter five States is devoted to evaluating differences in degree of boll weevil infestation in plantings of various lines, or crosses, and in cotton species gardens being maintained at the various Agricultural Experiment Stations.

Promising characters of resistance such as hairiness, red color, and the absence of glands are being evaluated in North Carolina. A breeder is incorporating several of these resistant characters into a single line of cotton.

In Arkansas, a search for resistance under a heavy boll weevil infestation is being made in several hundred breeding lines, crosses, and species planted at random in 20-foot row plots. Evaluations of resistance are made by an entomologist and a breeder by (1) determining comparative boll weevil emergence from infested squares collected from the various lines, (2) determining degrees of damage in bolls, and (3) evaluating fruit set and yield.

### Biological Control

Very little effort was indicated in this area of research with only a total of 0.9 scientist man year being expended in the States of Mississippi, Alabama, North Carolina, South Carolina, and Arkansas. In most instances this consisted of a study of parasites which emerged from field collected infested squares used for the purpose of rearing boll weevils for other studies. In South Carolina, limited studies are conducted in cages by ARS workers to determine if a parasitic nematode will destroy boll weevils when applied to woods trash in which they are hibernating. The adverse effects on the reproductive capacity of overwintered females infested with a native nematode in one locality are being studied by state workers in Arkansas.

### Cultural and Mechanical Control

Very little effort was indicated in this area of research with a total of 0.8 scientist man year being expended in the States of Texas, Mississippi, Louisiana, and Arkansas. These efforts are being devoted to a limited study of the effects of such practices as early stalk destruction, and the use of defoliants, dessicants and insecticides on weevil populations entering hibernation quarters and subsequent survival to infest the next year's crop.



### Economics and Cost Analysis of Boll Weevil Control

A total of 1.6 scientist man years of research is indicated for this study in Louisiana, Mississippi, Alabama, North Carolina, Arkansas, and Tennessee. In most instances the research is primarily an incidental evaluation of the cost of control and profits derived therefrom although comparative values of different control program approaches are receiving some attention. The services of an agricultural economist was not available for any of the studies. A study involving a team approach of an entomologist and an agricultural economist to determine the economics of boll weevil control at various levels of infestations is in the planning stage at Stoneville, Mississippi.

### Other Research

A total of 1.55 scientist man years in Texas, Mississippi, South Carolina, and Arkansas, are involved in activities which were not covered by the areas of research previously discussed. This involved studies of the effects of boll weevil control measures on beneficial and injurious insects, the development of better techniques in determining boll weevil infestations, and the improvement of survey methods.



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FINDINGS ON AN OVER-ALL RESEARCH PROGRAM  
ON THE BOLL WEEVIL PROBLEM

After discussions of the boll weevil problem and research needs with representatives in ARS, State Experiment Stations and industry, the working group has, based on its findings, outlined the following needs for an overall program of research to improve boll weevil control. This overall program will require the participation of State, Federal, and industry workers. The research emphasizes attacking the problem through basic investigations but recognizes fully the importance of meeting current applied boll weevil problems. The phases of research considered appropriate for Federal attention and support are discussed in the next section of this supplemental statement.

Chemical Control

Conventional Insecticides

These are the insecticides which are commonly used in boll weevil control at the present time. They are applied to growing cotton plants in the form of a dust or spray and remain largely on the surface of the plants. The boll weevils are killed, mainly, by being hit by the insecticide as it is applied, by contact with it from walking on the surface of the treated plants or by ingesting it through feeding on the plant. PROBLEM: More economical, more efficient, less hazardous insecticides to apply to growing cotton, are needed for use in the boll weevil control programs of growers. If resistance to phosphate insecticides develops as well as resistance to chlorinated hydrocarbon insecticides, chemicals with modes of action different from these will be needed.

Field Evaluation of Insecticides. PROBLEM: This is a major activity in all the areas visited by the working group and in most States one or more man years of scientist time is devoted to this research. It is of major importance and is the basis for recommendations for insecticidal control of the boll weevil. In this connection insecticides evaluated on the basis of application to large areas usually give results more nearly like those obtained under commercial conditions. An insecticide with less comparative effectiveness than a standard in a small-plot test may give satisfactory control when applied to large areas. RESEARCH: At the present time, field plot testing of boll weevil insecticides appears to be fairly adequately supported. However, considerably more manpower would be needed if the large area method of evaluating insecticides in the field is given more attention, or if there is an expansion of research to discover new insecticides, repellents, or attractants resulting in more materials being available that appear sufficiently promising to warrant field evaluation.



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Field Cage Research. PROBLEM: At present, field cages are often used to evaluate new materials before they are tested in small field plots. There are indications that the use of large field cages would be worth exploring as a possible substitute for small-plot field tests. They might serve as the step between laboratory evaluation and field evaluation on a large scale basis. The movement of boll weevils from plant to plant, from one section of the field to another and from field to field, appears to confound the research in small plots under field conditions. For this reason, the use of field cages varying in size from those covering one plant to those covering one acre, may be a better approach to gaining preliminary field information on boll weevil control than small plots. In these large cages, definite levels of boll weevil infestation could be maintained throughout the season without the variable of weevils moving into and out of the test areas, which may create false impressions of the effectiveness or ineffectiveness of the materials under test. However, the potential advantages of large cages may be offset by the expense of constructing and moving them to new locations as the need arises. Considerable manpower is needed to maintain and make studies in them. RESEARCH: Studies to fully determine the usefulness of large field cages appear well worthwhile. Developments in construction that would make them more economical and more easily moved deserves considerable attention. Entomologists with the help of engineers could probably do this work to best advantage.

Laboratory Evaluation of New Chemicals. PROBLEM: Materials are constantly being discovered that are toxic to various species of insects. Laboratory tests are usually the most economical and rapid way of determining if these materials show promise for control of the boll weevil. There is a need for evaluation of the performance of insecticides beyond the customary 3 to 5 day kill of adults, such as their effect on feeding and reproduction. RESEARCH: Testing of promising new insecticides is being done to a limited extent in the laboratory. Promising materials can be carefully tested under laboratory conditions including tests on cotton plants grown in greenhouses. This is an important phase of insecticide research and one that should be maintained, improved and strengthened to provide as much information as possible on new materials before they are taken into field cage or field tests. Evaluation of new chemicals may require tests to determine insecticidal activity, systemic action, attractancy and repellency. This type of research serves as a basis for obtaining leads for the development of potentially practical chemicals. Entomologists with adequate laboratory facilities who would work closely with chemists, are needed for this research.



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Resistance to Insecticides. PROBLEM: The boll weevil has developed resistance to some chlorinated hydrocarbon insecticides in some areas. This is a very serious problem since the recommended insecticide used by a grower one year may fail to give control the next. As a result he may suffer considerable crop loss even though he is correctly applying recommended materials.

(a) Occurrence and Locations. PROBLEM: Considerable work is now in progress in defining localities where resistance has developed. This involves laboratory testing of weevils collected from various areas in comparison with "normal" weevils and also making regular field observations. This is a very important practical problem and probably should receive attention wherever growers are having difficulty in obtaining satisfactory control with any of the insecticides recommended for the area. RESEARCH: This may require increased attention of entomologists as resistance in populations spread and farmers need to know the seriousness of the problem in their localities. The occurrence of resistance can usually be determined most accurately in laboratory tests.

(b) Seasonal Changes in Resistance. PROBLEM: Another very important element in the resistance problem is that weevils may increase in resistance to insecticides as the growing season progresses. However, some information is available indicating that the boll weevil may, under some circumstances, be difficult to kill with chlorinated hydrocarbon insecticides early in the season. The degree of resistance may depend on the amount of fat reserves in the weevils emerging from hibernation and the accumulation of fat in the weevil during the growing season. In other words, it may be that lean weevils are more susceptible to chlorinated hydrocarbon insecticides than fat weevils. RESEARCH: Further research on seasonal changes in resistance by entomologists is needed to explain the variations and extent of resistance and its importance in boll weevil control in different areas. This could probably be done with accuracy by laboratory tests on field collected weevils.

(c) Physiology of Resistance. PROBLEM: The most promising means of overcoming the effects of the development of resistance to



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insecticides in the boll weevil is through the study of the physiological changes which take place in the boll weevil that bring about resistance. Considerable basic work is now being done on the physiological mechanisms of resistance in the boll weevil. RESEARCH: Good research is getting under way. An increase in the number of insect physiologists working on this problem would increase the rate of progress. A good start in this work has been the initiation of southern regional project S-43, Mechanisms by Which the Boll Weevil and Other Insects Become Resistant to Insecticides. The first annual meeting of the technical committee of this new project has been called for February 1959. At the present time, Texas, Louisiana, and Georgia stations and ARS have contributing projects to this regional project. At the technical committee meetings, a fine opportunity should be provided to (1) review all work that has been done during the year in this field, (2) consider any major developments in other fields that might have a bearing on the research in this field and (3) plan a future program of research that would be the most productive.

#### Systemic Insecticides

PROBLEM: Systemic insecticides which could be applied to the seed and would then protect the cotton plant from boll weevil attack for 10 weeks by entering the sap stream of the cotton plant and concentrating in the areas where the boll weevil feed, without leaving a toxic residue at harvest, would probably be an ideal insecticide for use on cotton. Also an insecticide, that could be applied to the foliage and then be taken up into the plant or applied to the soil and be taken up by the roots, and then be translocated to the parts of the plant attacked by the boll weevil and protect them would be valuable as complete coverage of the cotton squares and bolls would not be necessary. Systemic insecticides are also generally less harmful to parasites, predators, and honey bees than other insecticides. Some progress has been made in the use of systemic insecticides as seed treatments for the early season control of thrips, spider mites and aphids attacking cotton but, none of these have shown sufficient promise in control of the boll weevil. RESEARCH: Basic research has recently been initiated to study ways of increasing uptake of the materials by the plants, inducing their translocation to new growth and fruiting forms and to develop means of chemically inducing resistance to the boll weevil in the cotton plant. Further studies of translocation of chemicals in the cotton plant are needed so that more effective ways of inducing it may be developed. The chemical structure of systemic insecticides in relation to the physiology of the plant should also be investigated. These studies require a team approach of insect physiologists, chemists with biochemical training and plant physiologists to discover the necessary leads for developing such insecticides for boll weevil control. It was the consensus of opinion that



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if an effective systemic insecticide applied as a seed treatment could be found, it would be an ideal method of control and might lead to eventual eradication of the pest. This type of control would probably not be excessively hazardous to bees or other pollinators, predators or parasites. However, such materials should disappear from the plant in time to avoid leaving a toxic residue in the cotton plants or seeds at time of harvest.

#### Development of New Chemicals For Boll Weevil Control

PROBLEM: The chemical industry has discovered the new insecticides that have proved highly effective against the boll weevil. This has, in the past, appeared to be a commercially profitable process but the development of resistance to insecticides by boll weevils has reduced the prospects for long periods of sale for a new insecticide. Also the cost of developing a material that can be marketed as an insecticide has increased. As a result, the supply of new insecticidal chemicals from commercial sources may be more limited in the future. RESEARCH: Basic research is needed to determine the relation of chemical structure to toxicity to the boll weevil and other types of physiological action upon this insect. More information of this nature on conventional insecticides, systemics, attractants, and repellents will be of material assistance to chemical companies and will facilitate their research on the development of new insecticides for boll weevil control. A team of chemists, entomologists, plant physiologists and soil scientists is needed for the various studies required. They should also investigate the relationship between chemical structure of insecticides and the effects on the cotton plant. Such a team would study materials which show toxicity to the boll weevil, and plan changes in the chemical structure of these compounds that might improve their effectiveness and safety. The research of this group would be directed toward the control of all stages of the weevil instead of toward adults only as is now the common practice. This type of approach has been quite successful in ARS in the development of herbicides and also in the development of insect repellents and attractants. Such a team on boll weevil research could obtain compounds they wished to evaluate from chemical companies and also could call attention of the chemical companies to any promising materials which might be developed into insecticides. No concerted effort is being made at the present time to determine the relationship between the chemical structure and biological activity of chemicals in the boll weevil. Most of the pioneering research of this nature is devoted to other species of insects.

#### Attractants and Repellents

PROBLEM: Very little progress is being made in the development of attractants or repellents for the boll weevil primarily because of the lack of basic knowledge of why and how the boll weevil is attracted



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to the cotton plant and lack of satisfactory techniques for measuring attractancy or repellency. Since the boll weevil attacks only the cotton plant, there is the possibility of developing attractants based on its response to this plant, as well as masking agents or repellents that would make cotton no longer attractive to the boll weevil.

Attractants. PROBLEM: Preliminary work that needs continuation, indicates that the boll weevil is attracted to cotton under laboratory conditions only from a relatively short distance (a foot or less). This may mean that any attractant for the boll weevil would be effective for only a very short distance. If applied to a cotton plant, it might attract the weevil for a short distance to the area covered by the attractant. RESEARCH: The study of attractants that might be the most profitable would involve materials which when applied to the cotton plant, would induce the boll weevil to feed on the particular area treated with the attractant. Such attractants could have an insecticide incorporated in them. In this way bait sprays or dusts might be developed that would be effective against the boll weevil. Great success has been obtained with this control method in the eradication of the Mediterranean fruit fly in Florida. This program was made possible by joint State-Federal basic research on fruit flies mainly in the Hawaiian Islands, which became infested with the oriental fruit fly a number of years ago. This type of research could be best handled by a team consisting of entomologists and chemists with adequate laboratory and field facilities.

Repellents. PROBLEM: Since the boll weevil feeds exclusively on cotton, there is a possibility of treating cotton in such a manner that it is no longer attractive to the boll weevil. RESEARCH: This type of research would require the services of chemists and entomologists. The chemists would prepare various materials such as plant extracts or other possible masking materials to apply to the cotton so that it would not attract the boll weevil. This is an unexplored field and no promising leads are available at the present time.

Morphology and Physiology of the Sense Organs. PROBLEM: Little is known about the location, structure or physiology of the sense organs of the boll weevil or even what senses are used by the weevil to distinguish the cotton plant from the other plants growing in an area. RESEARCH: The sense organs of boll weevil, including the sense of sight, smell, and taste, appear well worth investigating.



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Knowledge of what light waves or patterns the boll weevil would follow or avoid, if such exist, might easily lead to a better method of trapping boll weevil in large numbers or detecting very light infestations before they become serious. Knowledge of the taste and olfactory responses of boll weevil would also be very helpful in research on control measures and also in detecting very light infestations. To develop knowledge of the morphology of the sense organs would require the services of insect morphologists and adequate laboratory facilities for this type of research. To study the physiology of the sense organs would require insect physiologists with special interest in this type of problem and adequate laboratory and field facilities.

Nutrition of Boll Weevil. PROBLEM: The nutrition of the boll weevil is of primary importance from at least two points of view. One of these would be the development of artificial media on which boll weevil could be reared in large numbers throughout the year. These laboratory reared weevils would be of great value for experimental use and possibly in genetic control. Good progress is being made on this line of research and it seems probable that within the not too distant future, a satisfactory artificial medium for large scale rearing of boll weevil will be available. Another important point in research on nutrition is the determination of the materials which are essential to the boll weevil and upon which it will feed readily. This type of research has great promise and may lead to the development of a highly effective bait spray such as the Mediterranean fruit fly spray used in Florida. It also may lead to the discovery of a method or materials that would prevent the development of the weevil by destroying or modifying some essential nutrient in the plant. RESEARCH: A trained nutritionist, such as is currently employed, on this research is essential for progress in this field. The results obtained in the nutrition study should be reviewed by entomologists, chemists and plant physiologists and used in research designed to develop new approaches to boll weevil control. For example, the determination of the chemical components of pollens or plant extracts, which are required in chemically defined diets before females reared on them will oviposit readily, would be a valuable break-through. This might provide clues for finding highly attractive substances for use in bait sprays or clues for guidance in breeding cotton free of some substance essential to boll weevil development which would be useful in connection with varietal resistance research.



Hormones and Growth Regulators.

PROBLEM: Recent work on other insects has shown that there are several hormones in insects which control the rate of growth and the time of maturity of insects. One of these which has been named the juvenile hormone is currently under study at Harvard University. RESEARCH: This line of research offers theoretical possibilities of application to boll weevil control. At present, little, if anything, is known concerning these hormones in the boll weevil, or if the hormones which occur in other insects would have an effect upon the boll weevil and, if so, what the effect would be. This research on the physiology of the boll weevil with particular emphasis on the growth regulating mechanisms would appear to be a prerequisite for applied work in this area. This is a line of investigation that might eventually lead to the development of better boll weevil control. However, at present, it appears that research on the applied aspects might best be limited to exploratory work of an empirical nature in connection with the screening and evaluation of new types of chemicals.

Mode of Action of Insecticides.

PROBLEM: A better understanding of the mode of action of different types of insecticides in the weevil might reveal possible leads for developing more effective insecticides. The effects of insecticides used in boll weevil control on cotton plants are also of major importance. There have been some indications that certain insecticides stimulate the cotton plant to set a crop early and others may delay the setting of the fruit. A study of these relationships might reveal beneficial or detrimental effects which are now obscure. RESEARCH: Some work has been recently initiated in a team approach of an insect physiologist and a plant physiologist to study the mode of action of a systemic insecticide in the plant through the use of radioactive Thimet. Formerly, this type of research has been carried on mainly with other species of insects than the boll weevil. Entomologists who are well trained in physiology and biochemistry could make substantial progress in this type of research on the boll weevil. The team approach of insect and plant physiologists is essential in a study of the mode of action of systemic insecticides in both the insect and the plant.

Application of Insecticides.

PROBLEM: One of the most experienced people with whom the working group discussed boll weevil control stated that the most urgent problem in boll weevil control at present was an improvement in the methods of application of insecticides. Others also emphasized the importance of this problem. It was pointed out that during wet weather it was often



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impossible to get into the fields with ground equipment. Improvement in this respect is badly needed. When cotton plants become fairly well grown, the branches often intertwine between rows, especially those with a heavy top crop, making it impossible to operate ground equipment without injury to the plants. It was also suggested that research be conducted on planting cotton with wide rows left through the field. Ground equipment could be used to treat the cotton on either side. Some of the latest type of "jet nozzles" are reported to be able to cover crops for a distance of 40 feet on each side of the sprayer. RESEARCH: The application of insecticides to cotton by ground equipment, airplane, or helicopter, requires further study for improvement. More efficient plant coverage is needed. Ground equipment that can be operated in wet weather should be developed. The use of electro-static dust particles and spray droplets should be explored. Research on application problems would require the services of agricultural engineers and for aircraft applications would also require the services of a pilot with facilities for his use. This latter type of investigation is costly. It appears desirable at present to devote primary attention to basic studies on the development of suitable ground equipment. Such research might be coordinated with other cotton mechanization research. The research should be cooperative with entomologists who can appraise the effectiveness of the equipment and methods under development.

#### Insecticide Hazards.

PROBLEM: The application of insecticides to cotton may create residue hazards in the soil, for wildlife, for livestock pastured in cotton fields after harvest, for bees and for other beneficial insects. In addition if a toxic residue remains in cotton seed at harvest it would be a hazard in food and feed. The hazards of boll weevil insecticides to man, domestic animals, bees, other beneficial insects and wildlife during application should also be determined. These are problems which must be considered in connection with the development of all insecticides. Tests on all materials which come into commercial use must be made before recommendations to growers are made. RESEARCH: This line of research would need the services of chemists for chemical analyses and entomologists for the field phase of the study and to make bioassays. Some samples for residue determinations could probably be obtained with little extra effort by the entomologists who are making field evaluations of insecticides provided they are supplied in advance with proper information as to how and when samples should be collected. The effect that chemicals, that are used or are to be used commercially, have on the soil, soil microorganisms and on subsequent crops grown in soil in treated areas should be determined. Some research on residues in soils is being done under Regional Research Project S-22, Pesticide Residues-Determinations; Sampling; Effects on Plants and Soils. This project provides a good opportunity for obtaining information and for coordinating the research on residues resulting from insecticide treatments used for boll weevil control. The determination of the effects of insecticides used in boll weevil



control on bees and other beneficial insects would require the attention of entomologists.

Survey of Effectiveness of Boll Weevil Control Programs.

PROBLEM: In one discussion it was pointed out to the working group that recommendations for boll weevil control were sometimes based on the results obtained on "a few, small experimental plots." This did not imply that the plots were too small to be efficient or insufficient in number to warrant using them for the basis of recommendations. However, it did emphasize that in comparison with the acreage on which cotton was grown commercially the size of the experimental plots was small. It was brought out also that often an area has many acres in commercial cotton production which yields well and requires only a minimum expenditure for boll weevil control. The thought was expressed that these areas of commercial production should be given consideration in the formulation of boll weevil control recommendations. It was the general feeling that commercial chemical control of the boll weevil in the area under discussion was given due consideration in the formulation of recommendations issued in the past to the extent that accurate information on it was available. RESEARCH: If accurate information on commercial boll weevil control with insecticides in an area seems inadequate, consideration might be given to determining more accurately the type of control programs that large and small growers have used and how successful they have been. This would be in the nature of a study that would involve survey techniques such as are used in Agricultural Economics. A report based on adequate data to show what insecticide treatments had produced the best results for large and small growers, during the preceding season in an area would be useful in the preparation of insecticide recommendations for the coming year.

Breeding Cotton for Resistance to Boll Weevil

PROBLEM: The increasing difficulties arising from insecticidal control of the boll weevil and the success of breeding other crops for resistance to insects, for example, the resistance of wheat to the Hessian fly, has materially increased the interest in breeding cotton for resistance to boll weevil. RESEARCH: Although it is realized that developments in this approach to control may be long range requiring ten or more years for practical results, it was generally agreed that this approach to control had such great possibilities that it should be initiated and explored vigorously. On a short term basis, however, some improvement might be found in new varieties which are about ready for release at present. A beginning was reported in this line of research at six State experiment stations. Additional work seems highly desirable. This would require the efforts of plant breeders and entomologists working in teams.



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Search for Resistance.

PROBLEM: To find boll weevil resistance characteristics in cotton.

RESEARCH: Some types and sources of resistance have been discovered. Their potentialities should be fully explored. It also appears essential to make a complete survey of all species of cotton to determine all types and sources of resistance to boll weevil. As some species of cotton will not bloom in the United States, it would be necessary to make some of these tests at a location in Mexico or Central America where all species of cotton will bloom. Entomologists working with agronomists are needed for this research.

Evaluate Species and Hybrids.

PROBLEM: Where resistance is found, crosses between species might be made to bring together all the factors for resistance in a single line of cotton.

RESEARCH: The resistant characters would have to be incorporated in a commercial variety of cotton. This would require the services of plant breeders and entomologists working as teams.

Evaluate New Varieties and Current Strains of Cotton.

PROBLEM: Breeding material that is used to develop new varieties, as well as new varieties that are developed, should be evaluated for resistance to the boll weevil. RESEARCH: This work might be undertaken by a single group for all cotton breeders, commercial as well as State and ARS, throughout the boll weevil belt. This activity would fit in well with a general cotton breeding program. This type of evaluation requires a tremendous amount of detailed work during the fruiting period. It would require the services of entomologists and plant breeders supported by subprofessional assistants or junior scientists and a large amount of labor in season. The material should be evaluated not only for degree of attack by adults but for inhibition of development of eggs, larvae and pupae in squares and bolls and the effect on the reproductive rate of the weevils. Entomologists working with agronomists would be required for this work.

Biological Control

PROBLEM: This approach to control although it has received some attention in the past, has never been successfully relied on for boll weevil control. Its success against other insects seems to warrant its receiving considerably more attention in future research. Since the use of insecticides has become so widespread and the number of applications so frequent the value of natural biological control agents on cotton has probably decreased. Present day schedules of applying insecticides to cotton in all probability destroys a large part of the insect parasites and predators that may be in the cotton field or may quickly reduce the number that migrate into it during the season when insecticides are being applied. However, there



was a general feeling among those with whom this problem was discussed, that this was an area of research that needed reappraisal with attention to boll weevil diseases as well as parasites and predators. Perhaps some modern method of handling parasites or diseases, such as mass production in the laboratory, would make it practical to use them in place of insecticides or to develop an integrated program using parasites, diseases, and insecticides on cotton to control the boll weevil.

### Parasites and Predators.

**PROBLEM:** The conventional pattern of releasing parasites of the boll weevil with the expectation that they would become established and increase to sufficient numbers to control the boll weevil, has not been too successful. However, in certain areas and during certain years a fairly high percentage of parasites in boll weevil has been observed. The release of parasites during the early fruiting period with the hope that enough population build-up would occur to control the boll weevil would have little chance of success because of the intensive use of insecticides for boll weevil control. In cotton fields not treated with insecticide, ants and ground beetles would probably feed upon numerous boll weevil larvae and pupae in squares on the ground. **RESEARCH:** It has been suggested that an attempt be made to produce in the laboratory some of the parasites which feed on the boll weevil. These might be reared in the laboratory on suitable insects or by other means and released in the field in large numbers. It might be practical to rear these parasites at a low cost, perhaps as low as 25¢ a 1000. In such case, it would probably be possible to release 7 or 8 thousand parasites per acre for the cost of one insecticide application. If the release were timed to coincide with the emergence of the boll weevils from hibernation, such a high population of parasites might prevent the usual boll weevil build-up during the early part of the season. Another possibility would be to rear parasites on artificial media. Research to develop satisfactory media would be required for this. The collection of parasites and predators in the native home of the boll weevil in southern Mexico or Central America should be considered. Valuable parasites might be collected there, reared artificially in large numbers and released each season even though they are not sufficiently hardy to overwinter in the United States. Entomologists could begin this research by rearing parasites in large numbers in the laboratory for release in boll weevil infested fields and as soon as possible determine their value in boll weevil control. To assist in securing various parasites, all parasitized weevils collected by any entomologist working on boll weevil could be sent in for identification, culture, and evaluation of the parasite.



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Diseases.

PROBLEM: No specific diseases of boll weevil are known. However, overwintering boll weevils have been collected that were infested with nematodes. A nematode which feeds on a number of other insects was found in limited tests to be effective against boll weevil under certain conditions. Laboratory tests have indicated that certain pathogens from other insects will kill boll weevil. RESEARCH: It would seem desirable to survey the boll weevil more carefully for diseases and nematodes that might occur in various areas of the United States. It also probably would be worthwhile to survey the native home of the boll weevil for diseases and nematodes that might be prevalent in that section of the world. If these could be cultivated artificially and distributed widely in boll weevil infested areas, or applied in regular spray schedules, effective control might be obtained even though they did not survive the winter. The cost of such a program probably would not be prohibitive if highly efficient pathogens could be cultured and applied. Insect pathologists could begin surveying boll weevil for diseases and request that any diseased specimens be forwarded for study of the parasite affecting them. This appears to be a very promising line of research. These micro-organisms would probably be compatible with insecticide treatments.

Control of Hibernating Weevils

PROBLEM: The outstanding example of control of hibernating boll weevils has occurred in the Lower Rio Grande Valley in Texas. Destruction of cotton stalks is required in this area to retard the buildup and spread of pink bollworm. As a result, the boll weevil problem has been minimized. Early stalk destruction may not be profitable in all areas. In the Lower Rio Grande Valley there is a long growing season and cotton will continue to grow and bloom late in the fall allowing an opportunity for boll weevil to build up in large numbers and enter hibernation or feed throughout the winter.

Preventing Weevil Buildup in the Fall.

PROBLEM: Under many conditions weevils are allowed to develop and multiply in cotton squares and bolls that develop too late in the season to mature for harvest. If this source of food could be eliminated, the number of weevils entering hibernation might be substantially reduced. RESEARCH: Defoliation, dessication, application of insecticides or mechanical destruction of cotton after production is completed for the season and before the weevils are ready for hibernation might reduce the population of weevils entering hibernation. Preliminary results indicate that boll weevil adults may require a period of feeding of two or three weeks before entering hibernation in a condition that will permit winter survival.



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Any means of cutting off this food supply for adults and eliminating squares and bolls in which larvae could develop, at a sufficiently early date to prevent development of larvae and feeding of adults prior to going into hibernation, might result in considerable reduction in hibernating weevils. Further research is required to establish the conditions necessary in the fall that would lead to heavy winter mortality of overwintering weevils. The control of overwintering weevils on a community-wide basis is an effective approach to control and should be considered for use throughout the boll weevil belt. This line of research plus the two lines which follow would require the attention of entomologists studying the problem in various areas because the seasonal development and habits of the boll weevil can be expected to vary greatly.

#### Destruction of Weevils in Hibernation.

PROBLEM: Insecticides applied to areas in which weevils were hibernating have not been highly effective in destroying the weevil during the winter. This may have been due to the low temperatures or the types of insecticides used or both. Some hibernating weevils have been found infested with nematodes as mentioned above. RESEARCH: If this species of nematode could be cultured and distributed in hibernating areas, it might have considerable promise for control of the weevil especially in the humid parts of the boll weevil infested area. A study of hibernating weevils to determine if diseases are present among them, might disclose microorganisms that could be cultured and used to control weevils in hibernating areas. Also, there appears to be some possibility in using predators that feed on hibernating weevils. While most parasites are effective mainly at high temperatures, there are certain spiders which are reported to be effective predators at low temperatures. If these could be cultured and released in hibernating areas, extensive destruction of hibernating weevils might occur. Control of overwintering weevils on a community-wide or larger basis appears worth exploring further.



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Destruction of Hibernating Weevils in the Spring.

**PROBLEM:** Some years the number of boll weevils that emerged from hibernation was comparatively small. This may result from a severe winter. A means of killing the surviving weevils as they come out of hibernation in the spring might be a most effective point of attack on this pest because of the low numbers and apparently low vitality at that time. It is also reported that some weevils are more susceptible to certain insecticides at that time.

**RESEARCH:** Preliminary tests using potted cotton plants, in the squaring stage while the field planted cotton was in the pre-square stage, indicated that the hibernating weevils were attracted to the squaring plants. The application of insecticides for the control of emerging weevils when the cotton plants are small, might be an effective method of reducing the numbers materially especially if some bait could be added to these sprays or dusts. Trapping weevils as they come out of hibernation might be effective. For example, sticky screens which are used at present to measure the movement of boll weevils in the field in summer, might catch considerable numbers of weevils in the spring if the screens were strategically placed. Information is also needed on the reasons that boll weevils hit these screens. Are they attracted to them or do they just strike them accidentally in their normal flight? If the overwintering generation of weevils could be reduced to a sufficiently low level, the possibility of producing cotton without insecticide treatment would be greatly increased. Where insecticide applications were necessary, a much reduced program might be effective. Entomologists would be needed for this research.

Physiology of Diapause.

**PROBLEM:** Recent studies have indicated that boll weevils go into diapause during hibernation. Investigation of the physiology of diapause might reveal possible ways of inducing diapause at abnormal times or breaking it prematurely during the winter and thus cause the death of hibernating weevils. **RESEARCH:** Personnel would need to be trained in insect physiology and study the physiological changes that occur in larvae and adult weevils during the summer and fall for leads on the physiological basis of diapause.

Destruction of Weevils in Squares on the Ground

**PROBLEM:** If a high percentage of the squares that become infested with boll weevils and drop to the ground could be destroyed or treated to kill the larvae or pupae before the adults emerged, satisfactory control of the boll weevil might be obtained. One of the first methods that was tried for boll weevil control was picking up the squares by hand as they dropped on the ground. The cost and availability of labor has made this an impractical operation. In discussing this with the agricultural engineers, the working group was given reasonable assurance that a mechanical device for gathering the squares off the ground could be built. It was estimated that this device might pick



up the squares in an acre of cotton for about the cost of insecticide treatments. This control would be most feasible in small cotton and for first generation weevil control. If such a control method could be made sufficiently effective the necessity of making insecticide treatments during the later fruiting period might be diminished or avoided. Information is needed on the efficiency of the machine required to give control and how often it would have to be operated to prevent weevil emergence. This mechanical type of pickup might not be practical on hill conditions or in irrigated cotton where rains or irrigation water might wash the squares out of the cotton fields. In a great many areas where cotton is grown this would not be a limiting factor because the squares normally lie on the ground where they fall from the plant, and the problem of picking them up by suction should be comparatively simple. When they are stuck in the soil by rain such a procedure would be somewhat more difficult. Possibly, a combination procedure that would pick up the squares from the ground and also collect adult weevils from the small cotton plants might have possibilities. Another approach would be to treat the squares on the ground with an insecticide. Some material which would be highly toxic to both the boll weevil and weeds might be used as a combined weed and boll weevil control. A third possibility would be an adaptation of flame cultivation. However, preliminary work has shown that a flame hot enough to destroy weeds is not adequate to destroy boll weevil larvae in the squares. RESEARCH: A team approach of entomologists, agricultural engineers and chemists is needed to investigate these approaches to boll weevil control.

#### Boll Weevil, Cotton Plant, Soil, and Water Relations

PROBLEM: The modern practice of applying relatively large amounts of fertilizer to cotton and using supplemental irrigation when needed in cotton production, has affected the growth habits of the cotton plant. The effect of these changes upon boll weevil infestation and control is indicated to be of considerable importance. RESEARCH: A study of this nature would require a team approach involving an entomologist, plant physiologist and soil technologist. Changes in boll weevil infestation resulting from different fertilizer applications and irrigation schedules should be studied. This might be done most satisfactorily in large field cages.

#### Reproduction of the Boll Weevil

PROBLEM: Little is known in regard to the physiology of reproduction in the boll weevil. RESEARCH: Basic studies of physiology in relation to reproduction might develop leads which would assist in the control of this pest. This would require the services of an insect physiologist. A preliminary evaluation of a wide variety of chemicals for their effect on reproduction might develop some promising leads for further exploration.



### Factors that Influence Boll Weevil Infestations

**PROBLEM:** There is a marked difference in the way boll weevil infestations developed in different areas and in different seasons. Sometimes one grower who uses insecticides extensively harvests about the same crop as another grower who uses very little insecticide. Boll weevil infestations that look extremely threatening may subside without causing appreciable damage. Under other circumstances what appears to be a minor boll weevil infestation may develop into high infestations and serious damage within a short time. The factors that cause these changes need study to more accurately define them so that it will be possible to predict boll weevil infestations more exactly.

#### Level of Infestation.

**PROBLEM:** The present method of determining the level of boll weevil infestation requires considerable time and effort. If simpler methods could be discovered that would require less time and cover fields in more detail allowing for spot treatment with insecticides, more economical control could be effected. This problem is especially acute when the boll weevil population is very low early in the season just after the weevils have emerged from hibernation. **RESEARCH:** Some interesting leads on detecting boll weevil infestations have been found. One of these was the use of cotton plants that have been grown in pots in the greenhouse until they were in the squaring stage. These were placed in a field of young cotton in the pre-square stage at the time the boll weevils were coming out of hibernation. There was some indication that these plants collected a high percentage of the weevils in the field and might be used to determine the level of infestations in cotton fields up until the time that squaring began in the cotton planted in the field. Another method, using sticky screens, has been used to determine the movement of boll weevils in cotton fields. This method might have possibilities for determining changes in boll weevil infestations in cotton fields not only early in the season but throughout the season. Other systems might be developed. In any case, it would be necessary to correlate the collection of insects on the potted plants or the sticky screens with actual infestations in the field. This would need to be done under varying ecological conditions. Entomologists with adequate numbers of technical assistants would be needed for this type of investigation.

#### Weevil Movements.

**PROBLEM:** Many growers who have used an effective boll weevil control program early in the season find it necessary to continue to use insecticides throughout the season. This, in many cases, appears to be due to the migration of weevils from neighboring fields where a high degree of control has not been obtained. While specific data are not available on the maximum distance that boll weevils will travel in a single season, it has been reported that cotton growing sixty miles from any other cotton, which might be a source of boll weevil, has become infested during the season.



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**RESEARCH:** The extent and character of movements of boll weevils both into and out of hibernation and within cotton fields and among cotton fields, needs careful study, evaluation, and correlation with ecological conditions throughout the growing season. Entomologists with an adequate supply of technical assistants would be needed for these studies.

Effects of Climate and Stage of Plant Growth on Boll Weevil Infestations.

**PROBLEM:** The population dynamics of the boll weevil should be given careful study under varying conditions that exist in the boll weevil infested area. The number of weevils that could cause commercial damage in a cotton field should be determined at the various seasons of the year and under different climatic and growing conditions. **RESEARCH:** Such questions as "Will the boll weevil increase as rapidly on squares early in the season as late in the season?" if answered, could provide leads for more effective control. Entomologists with adequate help would be required for this work.

Influence of Boll Weevil Control Programs on Damage From Other Insects

**PROBLEM:** The frequent treatment with insecticides for boll weevil control has a tremendous effect upon the overall insect population in cotton fields. While this may control certain pests, it may also have a devastating effect on parasites and predators with the result that the natural balance of insect populations is badly upset. In some instances, the elimination of parasites and predators may cause an outbreak of species that are normally not numerous enough to damage cotton. The bollworm, cotton aphids, and spider mites are pests which may increase as a result of insecticide treatments for boll weevil. The application of insecticides might also seriously affect honey bees and other pollinators. **RESEARCH:** A careful study of various cotton insects in relation to their parasites, or predators, when insecticide treatments for boll weevils are made should be undertaken as a part of an overall study of the boll weevil problem. The effects of an early-season control program directed against the overwintering weevil, on subsequent populations of other insect pests, could be studied to good advantage in every state, or at least, on a regional basis. More information is needed on when these applications should be stopped and what insecticides could be used with minimum likelihood of increasing other insect problems. Research on the selection of insecticides and methods of use which have the least adverse effects to the honey bee and other pollinators is also of vital importance. Studies on the various beneficial insects would require the services of entomologists in various areas.



### Economics and Cost Analysis of Boll Weevil Control

**PROBLEM:** In the boll weevil infested area, the control of this pest is one of the major items of cost in the production of cotton. Better estimates of boll weevil losses in terms of pounds of lint and seed, and also determination of cost of control on that basis would be useful. Reduction in costs for the control of the boll weevil would make cotton more competitive with synthetic fibers. The working group discussed the matter of the economics of boll weevil control with economists at a number of the State stations and in USDA. The consensus of opinion appeared to be that determination of the cost of boll weevil control in relation to all other cotton growing practices and varying insecticide treatment schedules, was exceedingly complicated.

**RESEARCH:** It was the general feeling among economists that the best approach to studies on the economics of boll weevil control would be to obtain the services of an economist who would work with the entomologists doing research on boll weevil control. This economist would review field research plans and determine if economic data could be obtained from such studies, or if minor modifications in the plan would yield valuable data on the cost and profits from boll weevil control. It appears desirable that research on the economics of boll weevil control should include work on the development of techniques for economic studies. One suggestion that appears feasible is that studies first be undertaken of boll weevil infestations at various levels under field cage conditions to determine the relationship of infestation levels and the yield, maturity dates, and quality of cotton. Such research is being considered at present. This work would require the efforts of economists working part or full time with entomologists.

### Morphology of the Boll Weevil

**PROBLEM:** Little is known about the morphology of the boll weevil. More knowledge about it would provide valuable background information. A beginning in this field was mentioned previously in the study of the sense organs of the boll weevil. The morphology of these organs would provide a basis for physiological studies to determine what stimulates the sense organs of the boll weevil to cause it to respond in various ways.

**RESEARCH:** Research on morphology of the boll weevil would require the services of an entomologist trained in morphology. Morphologists in various institutions might undertake research on different systems of the insect. The reproductive, respiratory, digestive, or other systems could be studied to provide background information that might be useful in physiological and control studies.



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### Range of the Boll Weevil

There are indications that the boll weevil is extending its range in the cotton producing areas of the United States.

#### Westward Spread

**PROBLEM:** The boll weevil has recently become a major pest in the Presidio area of Texas. This is a westward movement of the pest. If the weevil has adapted itself to conditions in the Presidio area, it might increase the chances of spread into New Mexico, Arizona, and into California.

**RESEARCH:** While an extensive research program as a result of this development does not appear warranted at the present time, it seems desirable that periodic observations and studies be made by trained entomologists. These studies should include surveys to determine the presence or absence of the weevil in western areas adjacent to known infestations. A study of the ecological conditions in the western areas in which the boll weevil is surviving, and in adjacent areas where the boll weevil is not present would be well worthwhile. Basic genetic studies to determine if such strains are physiologically different from boll weevils in other areas might help to answer the question of adaptation.

#### Boll Weevil Survival in the Northern Part of the Cotton Belt.

**PROBLEM:** The boll weevil is a pest of cotton in some years almost to the northern limits of cotton production. There has been some evidence that the boll weevil is becoming more numerous in these areas. At one time a cold winter would apparently destroy the weevil to such a large extent that it would require several years of mild winters for it to reestablish itself in northern areas of cotton production. At the present time there appears to be an increase in the survival rate of the boll weevil in the northern cotton producing areas.

**RESEARCH:** This problem would not require extensive research but by cooperative research and by comparing the survival of weevils from northern areas with the survival of weevils from areas further south, an indication of increasing hardiness in the northern strains might be obtained. Such work might be supplemented by genetic studies to determine if strain difference exist. This would require the work of entomologists and geneticists.

### Genetics of the Boll Weevil

**PROBLEM:** Knowledge of the genetics of the boll weevil might be useful in control. The development of the male sterile technique for the control of insects, such as is employed against the screw-worm at present in Florida,



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has opened new possibilities for the genetic control of the boll weevil. With the development of a method of artificially rearing boll weevils, several possibilities along this line may develop.

#### Heredity of Resistance to Insecticides in the Boll Weevil

**PROBLEM:** This is a problem of major importance. In case resistance to insecticides is found in a certain area, the question naturally arises as to whether it is a permanent situation or one which may revert to susceptibility in a short time. Studies are being made to determine how many generations are required for resistance to develop and for reversion to occur.

**RESEARCH:** A study of the characteristic of resistance in boll weevil and also the amount of time required for reversion to susceptibility, if that is possible, would provide good background information on which to build a control program for resistant weevils. Studies of this type are under way but need to be tied in with studies of a geneticist for a better understanding of heritability. This research would require the services of geneticists and entomologists.

#### Variations in Boll Weevil Populations

**PROBLEM:** A genetic study of the variability in boll weevil populations in and among different areas may indicate differences not now known to exist. These may have an important bearing on control.

**RESEARCH:** This research would require a study by geneticists and entomologists, but the work might be done in the laboratory at one location by obtaining strains from different areas.

#### Effects of Boll Weevil Injury to Cotton Bolls

**PROBLEM:** In locations where there is a high infestation of boll weevil and the cotton has stopped squaring the weevils often feed on an oviposit in bolls and the larvae develop in the bolls. This happens most frequently late in the season. The development of larvae in the boll causes damage to one or more locks of cotton. This damages both the yield and quality of cotton produced in the boll. Under certain conditions weevil damage to bolls may increase the incidence of boll rot.

**RESEARCH:** This research would need study by entomologists in various areas to learn the extent and severity of the damage under different conditions. The best progress in research on boll rot would probably be made by entomologists and plant pathologists working together.



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### Effects of Boll Weevil Feeding on Squares

**PROBLEM:** An interesting basic study is on the effect of the feeding of the boll weevil on cotton squares. It is well known that the cotton plant sheds its squares when attacked by the boll weevil. If the physiological action of the boll weevil on the squares of cotton were known, this might provide an opening for the development of a control procedure utilizing these facts.

**RESEARCH:** This study has been initiated and requires knowledge of both the physiology of the insect and the cotton plant.

### Coordination of Overall Research Program

An overall boll weevil research program which involves participation by the State Experiment Stations, the USDA, and industry would probably be benefitted by some method for the exchange of current results, plans, and ideas. The method should be as simple and inexpensive as possible and designed to serve the scientists engaged in boll weevil research. An overall technical committee on the boll weevil problem could render real service in this connection. The working group found that most of the individuals questioned on the desirability of forming a technical committee agreed that such a committee could make a valuable contribution to boll weevil research. There appeared to be general agreement that the members of such a committee should be scientists directly engaged in boll weevil research and represent the major areas of investigation on the boll weevil problem and the organizations supporting such investigations.



FINDINGS ON NEEDS FOR A FEDERAL PROGRAM OF  
RESEARCH TO HELP MEET THE BOLL WEEVIL PROBLEM

A comprehensive research program on the boll weevil will require the joint efforts of the industry, the State Agricultural Experiment Stations, and the U. S. Department of Agriculture. These agencies must share responsibilities for the research required and each is in position to make vital contributions to the solution of this major problem of the cotton industry.

Acting on instructions of the Secretary of Agriculture, the working group gave special consideration to the role that the Federal government might appropriately take in efforts to help meet the over-all need for research on the boll weevil problem. Attention was given to research areas of broad significance, fully recognizing the responsibilities of and the need for the States to give appropriate attention to the many research problems that are primarily of local or State significance. The group also recognized the important role of various segments of industry in the past, particularly the agricultural chemical industry, and the vital role they must continue to assume in the future, in research and development on materials required for boll weevil control.

The study has revealed important and potentially productive areas of research on the boll weevil which are regarded appropriate for Federal attention and support. These involve research problems that are now receiving little or no attention, as well as those lines of research now under investigation which are inadequately supported in scientific manpower, operating funds, and facilities. The study has also brought to light areas of research both basic and applied of equal importance that the States might wish to consider for attention and support. The State stations may wish to consider the needs for an expanded research program to investigate various problems suggested by this study. Examples of such problems are given on page 49 in connection with the discussion of the relationship of the federal program to other research activities.

Scientists concerned with boll weevil research and leaders in the cotton industry have come to realize that complete producer dependence on the use of conventional insecticides is not a satisfactory method of coping with the boll weevil problem. This is apparent because of the growing problem of insect resistance to insecticides, the steady increase in the current cost of chemical control measures, the intensification of other cotton insect problems created by the use of presently available insecticides for boll weevil control, and the apprehension of wildlife conservationists, apiculturists, and even public health officials of the potential hazards of the insecticides currently in use. These are underlying factors which justify a strong research program designed to



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develop for immediate use more efficient and safer chemicals; to explore new kinds and new ways to employ chemicals for maximum efficiency, safety, and economy; and from a longer range viewpoint to develop methods of controlling the boll weevil which do not place complete reliance on chemicals.

Scientists engaged in boll weevil research in the past have contributed far more to the economical production of cotton than is generally realized. Without the knowledge of the problem and materials now available to control the boll weevil, most growers could not remain in the business of cotton production. Research workers now devoting their efforts to the boll weevil problem are well aware, however, of the shortcomings of current control measures and the lack of reserves in basic knowledge on which to draw in the event of an emergency situation such as widespread resistance to all currently available insecticides. A substantial portion of the efforts of these scientists has recently been redirected toward the development of a fundamental research program designed to provide basic information which might lead to better methods of boll weevil control. However, only certain segments of the many research problems suggested are now being investigated with available resources. Most of the current effort in both Federal and State programs is still required to meet the month to month and year to year problems that are encountered in constantly changing conditions relating to cotton production practices and problems. The available scientific staff and other resources are too limited to permit a concerted effort on new approaches which specialists agree offer good possibilities of leading to better control or even eventual eradication of the pest.

The nature and scope of proposed work and the organization and location of additional Federal support suggested by the study, together with justification of need for the research and facilities, are presented in the discussion that follows. General relationships of the proposed new program of work to current Federal, State, and industry research, as well as to the overall need, will be pointed out in this section of the Supplemental Statement. A more detailed analysis of these relationships can be made by referring to the previous two sections of the Supplemental Statement in which the nature and scope of current research and of research required for an overall, more comprehensive program are presented in considerable detail.

The need for additional Federal research falls into two categories. The first provides for the bolstering of current work at three of the six locations where Federal research on the boll weevil is now underway so that the scientists employed on certain broad basic problems will be adequately supported with subprofessional personnel, operating funds, and facilities. The second, which constitutes the major effort, provides



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for the establishment of a new laboratory and staff of scientists to concentrate on a number of specific problems with particular emphasis on new approaches to boll weevil control.

#### Additional Support for Scientists on Research Now in Progress

The study of existing Federal work clearly established the desirability of adequately supporting the basic research now under way. The study revealed that the scientists currently employed on this work cannot carry on their programs with maximum efficiency because of inadequate subprofessional help, operating funds, and facilities. The State and Federal staffs who are cooperating in research at College Station, Texas; Baton Rouge, Louisiana; and Florence, South Carolina, emphasized this deficiency as well as the lack of suitable facilities. They recommended that, in considering the need for an expansion of boll weevil research, attention should first be given to the need for research under way.

The working group recognizes the merits of this recommendation and concurs in the view that the scientists now engaged in important basic research at College Station, Baton Rouge, and Florence be provided with more assistance in the subprofessional or junior scientists categories and that suitable facilities, particularly greenhouse-headhouse installations, be provided at each of the three locations. To attain the proper balance between scientists and supporting personnel and to provide more funds for operations, it was indicated that the current annual station budgets should be increased by about one-half.

Such additional financial support and facilities would permit intensification and improvement in the research at College Station on the nutrition of the boll weevil and the feeding and reproduction responses of the insect to various factors in the diet. It would also permit more intensive effort on boll weevil rearing methods. The basic research now under way on the translocation and mode of action of systemic insecticides in the cotton plant would also be expedited.

At Baton Rouge, Louisiana, the vitally important basic investigations on the nature and cause of insecticide resistance in the boll weevil and how to correct or avoid such resistance would be intensified.

At Florence, South Carolina, the additional support would facilitate the studies now under way on the migration of the boll weevil to and from hibernation quarters and from field to field. It would also permit an intensification of studies to determine the degree of boll weevil control required early in the spring to assure sufficient delay in boll weevil build up to avoid economic damage before the cotton crop is set. Information of this kind is important in determining the proper timing of boll weevil treatments for the most effective and economical control and the importance of community effort in minimizing the number of treatments.



### Establishment of a New Federal Boll Weevil Research Laboratory

The study revealed surprising agreement by scientists as to the kind of research that is needed to help meet the boll weevil problem. However, views as to the manner in which a new Federal program of research could best serve the over-all need differed substantially by the various groups consulted. In general, the views of Land Grant College staffs were to place emphasis on the expansion of existing Federal cooperative programs and to initiate new Federal work in other States in cooperation with such States on promising lines of research they had under way that needed to be broadened in scope. The opinions of Federal and industry groups generally indicated the desirability of establishing in one location a corps of research scientists representing different disciplines, who would concentrate in a team approach on the various new areas of research that are proposed as appropriate for Federal attention.

Industry and Federal groups agreed that in the event that a major central facility and research group is established such facility should be located at a Land Grant College. Advantages in such location are many. The research staff would have access to the good library facilities available at such institutions. The research workers could consult with and receive the advice and cooperation of college staff members in different departments. Graduate and other well qualified agricultural students would be available for employment on a part-time basis and in many instances could develop specific lines of basic and applied research on the boll weevil problem which would be both advantageous to the program and to the student in meeting his graduate study requirements. Experience has also shown that agricultural scientists in general prefer to be located at Land Grant Colleges, particularly when engaged in basic research. The recruitment and retainment of a well qualified and experienced scientific staff would, therefore, be facilitated at a Land Grant College location.

The working group has weighed the views of the various groups on the matter of organization and procedure in carrying out an expanded Federal program of research on the boll weevil. It has taken into account the nature of the program and the scientific disciplines required to develop it.

From these considerations it appears that a Federal research program could contribute to the overall effort most effectively by concentrating the new work in one location in a well equipped laboratory.

In considering the location for such work, State College, Mississippi, appears most desirable from an overall standpoint. Mississippi is near the center of the boll weevil area. Cotton growing conditions in the vicinity of State College are fairly representative of Southern and Southeastern cotton growing conditions, and the location is only 50 miles from the Mississippi Delta, one of the Nation's principal cotton producing areas where the boll weevil problem is a major factor in production.



## Nature and Scope of a New Federal Research Program

Chemical Control

Chemicals now provide the only generally practical way to deal with the boll weevil problem. It is recognized by scientists that for the foreseeable future, the farmer must continue to rely on chemical control measures. Current research effort on chemical control is devoted primarily to the development of new insecticides of the type that destroy the adult insect on contact. Insecticides currently in use include aldrin, BHC, calcium arsenate, dieldrin, endrin, Guthion, heptachlor, malathion, methyl parathion, toxaphene, or various combinations of these and other insecticides. Research on chemicals in the past involved the joint effort of scientists in industry, in the States, and in the government. Future research in this area will require the continued cooperation and combined effort of these groups.

In considering the overall need for research on chemicals, there was almost unanimous agreement that expansion of Federal research would contribute most to the overall effort if the research emphasized new approaches to chemical control. The type of research proposed included: (1) systemics for seed, soil, or foliage treatment that would destroy both adults and immature stages in squares; (2) baits and other attractive substances, and (3) exploration of the possibilities of developing new chemicals which destroy the boll weevil by regulating their growth such as juvenile insect hormones which investigators at Harvard University and certain foreign institutions have shown to be highly active in certain stages of insects.

Although it was agreed that emphasis on new chemical approaches to boll weevil control needed major research attention, it was generally recognized that in view of the insecticide resistance problem, which makes it essential to have available new and proven effective substitute chemicals, research on the development of conventional type insecticides needed more adequate support. In the search for such substitute materials more information is needed on the relationship of chemical structure to toxicity to the boll weevil. Broader, more rapid, and more precise appraisals of the potential value of candidate materials should be developed at the central laboratory in order to select as quickly and accurately as possible those that are most promising and desirable for further research and development by the State experiment stations, existing Federal cotton insect research laboratories, and by industry.

Systemics represent a relatively new approach to chemical control. Entomologists engaged in research on the boll weevil are unanimous in their opinion that the development of a systemic insecticide that was highly effective in controlling the boll weevil and would not leave an



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objectionable residue at harvest would be a major breakthrough in chemical control for this pest. It would approach the ideal as a chemical control measure. In view of the progress in controlling other insects through systemic chemicals, there is reason for optimism in successfully meeting the boll weevil problem through a concerted and well planned program of investigation on this control approach. If a material were found that would kill adults and prevent eggs, larval or pupal development for 10 weeks following foliage treatment, most of the objections and limitations of conventional insecticides would be overcome. Such a material might even provide a practical means of eradicating the insect. There appears to be ample justification, therefore, for a major effort on the systemic approach to boll weevil control.

The development of attractive substances, which have proved so successful in controlling and eradicating the Mediterranean fruit fly, was regarded by most scientists to be another potentially fruitful area of investigation for boll weevil control. The findings of the working group indicates that research in this direction on the boll weevil has not advanced sufficiently to estimate the chances for success. However, observations on boll weevil concentrations on fruiting cotton early in the spring and on the feeding and oviposition responses of the insect in the laboratory to various kinds of nutritional media containing portions of cotton plants, other plant products, and other materials, supports the view of many that research on baits or attractants should be one of the important areas of investigation in the Federal program.

The possibility of utilizing growth regulating substances to control the boll weevil is regarded as another new approach that needs to be explored in connection with work on chemicals. Work in this area should be regarded long-range in character and basic investigations on the hormone and enzyme systems of the insect as proposed in connection with a discussion of basic insect physiology, plant physiology, and ecology should be initiated. However, in connection with an overall search for more effective, safer, and more economical chemicals for boll weevil control, the investigations should include some work of an empirical nature in a search for materials that exhibit growth regulatory characteristics. The leads obtained could be fully exploited by chemists and entomologists in a more concerted approach to this problem.

A well rounded research program along lines indicated for the purpose of developing more efficient, safer, and more economical chemicals for boll weevil control will require a group of specialists who will work as a closely coordinated team on both basic and applied aspects of the problem. It is estimated that a scientific staff consisting of three entomologists, three chemists, one plant physiologist, one soil scientist will be required to carry out the program on chemicals outlined.



The scientists should be adequately supported with sub-professional assistants. Facilities and equipment would be needed for maintaining insects for biological tests, plant material for studying responses of plants to chemicals under study, and for a study of the effect of various soil and soil-water management systems on the efficacy of the chemicals under development.

The chemists would work with entomologists in a study of the relationship of chemical structure and the biological activity of conventional insecticides, systemics, attractants, growth regulatory substances, and other potentially useful chemicals, for destruction of adult boll weevils, eggs, larvae, and pupae. They would be aided by the findings of basic research scientists who are studying the mode of action of insecticides in the boll weevil and in the cotton plant. Chemists on the team would synthesize materials as needed for tests by entomologists in order to determine the types of chemical structures that are most likely to lead to more effective and more economical ways to control the insect. The group would work with industry in obtaining a wide variety of compounds for evaluation as insecticides, attractants, systemics, or other types of biological activity. Promising chemicals would be given sufficient preliminary tests against the boll weevil and the cotton plant to determine if they are worthy of further testing. Information obtained would be made available to other Federal and State investigators concerned primarily with field evaluations so that materials worthy of field tests could be investigated in practical control. The plant physiologists would devote primary attention to the physiological effects of promising compounds on plants such as the effect on growth, fruiting behavior, maturity, and final yields.

The soil scientists would devote primary effort to systemic insecticides applied to the soil with a view to increasing their rate of availability, rate of absorption by roots and duration of effectiveness in controlling the boll weevil.

The scientists on chemical research could serve not only as the central corps of investigators to obtain basic information on the potential value of all types of chemicals for boll weevil control but also act as a clearing house for information which could be made available to those investigators in State, Federal, or industrial research institutions who are primarily concerned with the practical development of chemicals for boll weevil control. The chemists would also prepare special chemical compounds needed in the conduct of basic research on the mode of action of chemicals underway at the central laboratory and at other laboratories. Analyses would be made as required to establish the extent and nature of residues that appear in cotton seed products.



Development of Varieties Resistant to the Boll Weevil

Cotton varieties with satisfactory agronomic characteristics which are highly resistant to boll weevil attack or damage would be the most desirable and economical long-range solution to the boll weevil problem. This was the unanimous opinion of all scientists consulted and they recommended that a substantial portion of an expanded research effort be devoted to this approach to boll weevil control.

There is every reason to believe that a concerted cooperative research effort in this direction by the States, Federal government, and industry would lead to substantial progress. This belief is based on the successes that have been achieved by teams of entomologists and plant geneticists working on varietal resistance in various crops to other major pests. Hessian fly resistant wheats, European corn borer resistant corn, and spotted alfalfa aphid resistant alfalfa are examples of success through this approach to insect control.

Due to necessary emphasis on chemicals and other shorter range solutions to the boll weevil problem, very little attention in the past has been devoted to varietal resistance to the boll weevil. However, during the past several years six states have initiated research on this approach to control. Preliminary results of these investigations are encouraging. Several characteristics in cotton varieties, either morphological or physiological, have been shown to reduce the degree of boll weevil damage. Such work should be expanded in these states and initiated by others.

The Federal government is in a good position to actively participate in an over-all program of research, both basic and applied, on varietal resistance to the boll weevil. It has active cooperative research underway on various cotton improvement programs involving a number of other characteristics. It has access to many species and varieties of cottons.

The development of an over-all program to search for boll weevil resistant characteristics and to incorporate them into desirable varieties will require the cooperation of plant breeders and entomologists in the State Agricultural Experiment Stations, the U. S. Department of Agriculture, and the cotton industry. It is estimated that an adequate Federal staff should consist of three entomologists and two plant geneticists, adequately supported with sub-professional assistants and laborers.

The scientists should cooperate with State and private cotton breeders in a search for boll weevil resistant germ plasm. Various cotton species and crosses should be tested for boll weevil resistance, including varieties which flower only in tropical areas. Initially,



considerable emphasis must be given to the development of suitable techniques for measuring boll weevil resistance under controlled conditions so that tests can be undertaken throughout the year. Plant geneticists and entomologists would conduct basic investigations in efforts to determine the nature of resistance in different varieties that are found through an over-all program. Facilities and personnel should be provided for routine testing for boll weevil resistance in varieties submitted by Federal, State, and industry breeders who are engaged in cotton improvement programs.

A major breakthrough in finding highly resistant characteristics in cotton could provide a complete solution to the boll weevil problem. However, even a low level of resistance, in commercial and otherwise desirable varieties, would, without additional production costs, save the grower millions of dollars annually.

#### Basic Investigations on Insect and Plant Physiology and Ecology

State and Federal research laboratories now have underway research on a number of fundamental problems relating to boll weevil physiology and ecology. Excellent basic research is now underway on boll weevil nutrition, on the nature and cause of insecticide resistance in the boll weevil, on changes in the physiology and behavior of the insect in relation to diapause and on various ecological studies. However, the study by the working group pointed up a general lack of information on a number of aspects of boll weevil development, behavior, and ecology and their relationship to the cotton plant. Due to differences in boll weevil habits and behavior in different areas, certain biological, physiological, and ecological studies could be carried out most advantageously by investigators in existing state laboratories. A consideration of the over-all need for basic research has indicated, however, certain studies not receiving attention that would be appropriate for activation in the new Federal laboratory.

It is proposed that the new laboratory staff include the following senior scientists for research in this area: two insect physiologists, one plant physiologist, and one insect ecologist.

The insect physiologists would concentrate on a thorough study of the physiology of the boll weevil with particular emphasis on the growth regulating mechanisms in the insect and to obtain basic information on ways of upsetting such mechanisms. The research would involve studies of hormone and enzyme systems and how they govern growth, reproduction, and certain behavioral characteristics such as hibernation and migration. Coincident with such study on the insect, basic research should be undertaken on the interrelationship of the insects development and behavior and the physiological changes in the cotton plant. Investigations of the nature proposed would provide basic



information that would guide research on chemical methods of control involving the development of growth regulating chemicals, attractants, and systemics. Ecological studies on factors influencing population dynamics of the insect, movement of the insects in relation to stages of growth of the cotton plant and factors governing selection of hibernation places would provide basic information which would help guide research on ways to control the boll weevil by directing efforts on the insect just prior to hibernation, during hibernation, and immediately after emergence from hibernation in the spring.

### Biological Control

Biological control agents have in the past offered little promise as a means of boll weevil control. In fact, the necessity for dependence on chemicals or the adoption of rigid cultural measures to control the boll weevil has virtually eliminated natural insect agents as a factor in reducing boll weevil abundance.

The working group found that opinions as to the need for research on biological control methods varied considerably among the scientists consulted. Some lack confidence in this approach to boll weevil control, others were firm in their views that in a comprehensive program of research on the pest, the possibilities of developing ways to use biological agents should be fully explored, since they might prevent the need for the use of chemicals.

The lines of investigation proposed included work on parasites and predators, insect diseases, and on genetic approaches. A study of the different lines of research suggested would require the service of one insect pathologist, one entomologist (specialist on parasites and predators), and one insect geneticist.

The insect pathologist, with the help of field entomologists, would look for naturally occurring diseases of the boll weevil, including a search for such diseases in the natural home of the boll weevil. Any disease organisms--bacteria, protozoa, nematodes, viruses, or fungi found would first be investigated under laboratory conditions. This would involve identification of the organisms, methods for their culture and a determination of the degree of virulence. Pathogens showing promise would be given preliminary field tests in cooperation with entomologists engaged in conducting field tests.

Current work on boll weevil pathogens in the Federal program is limited to incidental observations and tests with a disease carried to insects by a nematode. Workers with the Arkansas Agricultural Experiment Station have conducted some work on a naturally occurring nematode that attacks the boll weevil in hibernation and which prevents normal egg production by the insect. It would be desirable to intensify



research on such organisms in cooperative studies. Research on micro-organisms that are compatible with insecticidal control are especially desirable.

In the work on boll weevil parasites and predators, any such natural enemies found in the United States or in the native home of the boll weevil, would be investigated under laboratory conditions giving primary attention to a determination of their potential value for boll weevil control when released at regular intervals in large numbers. Field trials that appear desirable would be undertaken with the assistance of field entomologists with State or Federal laboratories.

In addition to investigations on possible use of parasites and predators of the boll weevil, the entomologist assigned to the work would conduct investigations as needed to determine the effects of boll weevil insecticides on the honey bee, parasites, predators, and other beneficial insects.

The insect geneticist would explore the possible use of sexually sterile male boll weevils or other genetic methods as a means of boll weevil control or eradication. The advances that have been made in the mass rearing of the boll weevil suggests that it may be possible to produce large numbers of the insect at relatively low cost. This would result in the possibility of economically producing and releasing in cotton fields a dominant number of sterile male insects under conditions of low natural populations and thus prevent boll weevil build up to damaging levels. A discussion of other genetic approaches to boll weevil control brought out the theoretical possibility of developing deficiencies in boll weevil strains that would not be detrimental in mass production but which would prevent normal survival in the field. The development of physiological strains in which the adults could not hibernate successfully, or strains in which the larvae could not develop normally in squares or bolls would be examples of such genetic approaches to boll weevil control.

#### Engineering Research on Boll Weevil

The study of current research on the boll weevil revealed the absence of a concerted program of investigation, basic and applied, on methods and equipment for applying chemicals or on the development of other equipment such as mechanical devices for destroying infested squares on the ground. The research work underway by agricultural engineers is limited in scope.

A well qualified research engineer adequately supported with sub-professional assistants would be needed on the team of scientists to



concentrate on basic research pointing to the development of efficient equipment and methods of application of materials required for boll weevil control. There is particularly an urgent need for basic information on the best spray or dust patterns and the most efficient and most economical way to achieve the desired patterns. Basic work on more efficient deposition of dust particles electrically charged which is underway at North Carolina suggests the need for more research of this type. Basic research of this nature should be of material benefit to other engineering research directed more specifically to the most practical ways to apply insecticides under the different local conditions encountered in various States.

#### Economic and Cost Analysis Research on Boll Weevil Control

The importance of research on the economics of boll weevil control was generally recognized by the various groups consulted. There is need for such study in almost every major cotton growing area because of differences in cotton growing practices and conditions and the variations in the type of control programs recommended. Much of such research needs State attention and support. It was generally agreed, however, that research on economics of boll weevil control should be included in an expanded Federal program. Such research should be directed at the development of techniques and to broader problems such as the relative costs of different types of control programs under investigation. The agricultural economist would assist in the planning and execution of various field experiments on boll weevil control and concurrently study the economics of control in such experiments. When to start and stop applying insecticide treatments for most economical boll weevil control should be investigated in relation to levels of infestation and stage of crop maturity.

#### Listing of Lines of Research and Scientific Staff Requirements for a New Federal Boll Weevil Research Laboratory

By way of a summary the major lines of research and an estimate of the number and type of specialists required to conduct the research are listed below. Each senior scientist should have assigned to the project an adequate number of subprofessional assistants to carry forward the research with maximum efficiency:

##### 1. Chemical Control

- Three entomologists
- Three chemists
- One plant physiologist
- One soil scientist



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2. Development of Resistant Varieties

Three entomologists  
Two plant geneticists

3. Basic Insect and Plant Physiology and Ecology

Two insect physiologists  
One plant physiologist  
One insect ecologist

4. Biological Control

One insect pathologist  
One entomologist  
One insect geneticist

5. Engineering Research

One agricultural engineer

6. Economics Research

One agricultural economist

TOTAL: 22 Senior Scientists

Facility Requirements for a New Federal Laboratory

In order to carry out the program of research outlined as appropriate for Federal attention at a central location, it will be necessary to provide suitable laboratory and office space for a staff of 22 senior scientists and supporting personnel. The facilities should provide for laboratories well equipped to undertake basic research. In addition to the main laboratory installation, greenhouse, headhouse and outdoor insectary facilities will be required. Land must be provided for building and field plots.

Relationship of the New Federal Research Program to Other  
Federal, State and Industry Research Activities

The nature and scope of the research proposed is based on the findings of the working group and reflects the consensus of opinion of the many scientists consulted as to the most urgent needs for new research that



would be appropriate for Federal attention and support. However, it is emphasized that the Federal program outlined represents only a part of the total need for research on the boll weevil.

While the research activities that might be undertaken by the State stations would be developed by them, it seems appropriate to list some of the lines of study which were proposed to the working group that might be considered for initiation or expansion by the State stations. These include as examples, (1) expansion of work on the testing of new insecticides with particular reference to evaluation on community wide basis; (2) a study of the effect of various insecticide treatment schedules on natural enemies of other important cotton insect pests; (3) a more accurate determination of the effect on cotton yield and quality of different levels of boll weevil infestations during various fruiting periods of the plant, especially in late bolls; (4) studies on the occurrence and seasonal changes in resistance of the boll weevil to insecticides; (5) more precise basic information on the time, extent and distance of movement of boll weevils to and from hibernating areas and from field to field; (6) basic studies on factors governing diapause and selection of hibernation sites in different areas; (7) a study of the relationship of soil and water management practices to boll weevil development in various areas; (8) a study of cotton varieties resistant to boll weevil attack with particular reference to varieties adapted to various State or local areas; (9) basic studies on the morphology and physiology of the sense organs and other organs and systems in the boll weevil; (10) factors governing boll weevil behavior and movement, such as the age and physiological condition of the plant under various ecological conditions.

It was suggested to the working group that additional support somewhat comparable in total scope to the outlined Federal program be provided by the States through appropriate sources in order that they will be in position to initiate research on problems such as those listed, many of which need to be considered in relation to local practices and environmental conditions.

In the conduct of the expanded research program outlined, the additional support indicated for the current programs at College Station, Texas; Baton Rouge, Louisiana; and Florence, South Carolina, would contribute directly to the strengthening of cooperative work already under way.

The proposed new boll weevil laboratory would concentrate on the broader aspects of the boll weevil problem. The laboratory should coordinate its program of research with that of other Federal programs under way and cooperate closely with the States and industry in meeting the overall problem of the boll weevil.



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The laboratory should also maintain close contact with various industries concerned with boll weevil research and development to enlist their aid and to cooperate with the industries in their efforts to put into practical use any new developments that may help improve boll weevil control.

The research staff, to the extent that the college is in position to cooperate, should maintain close relationships with various Departments in the Land Grant College where the laboratory is to be located. It should take full advantage of any assistance that appropriate scientists in such departments might be in position to provide.

It is suggested, that in order to develop a program which will best meet the over-all and changing needs for research, that a technical boll weevil research committee composed of scientists doing research on the boll weevil, be formed representing the States, industry, and the U. S. Department of Agriculture. The objective of such a committee would be to facilitate the exchange of current research results , and coordinate plans for future research in an over-all effort to solve the boll weevil problem.



LIST OF AGENCIES, INSTITUTIONS, AND INDIVIDUAL PARTICIPANTS  
CONSULTED BY THE WORKING GROUP ON BOLL WEEVIL RESEARCH PROBLEMS

The working group consisted of E. R. McGovran, H. G. Johnston, E. F. Knipling, Chairman, and C. R. Parencia, Secretary, met with the agencies and institutions, including names of individuals participating, listed below. Information was obtained on the boll weevil problem, current research underway, and research needs to meet the problem. The conferences on the average lasted about one day with a range of one half to one and one-half days:

Agricultural Engineering Research Division  
September 22, A.M., 1958, Beltsville, Md.

Dr. E. G. McKibben, Director, Agr. Eng. Res. Division, U.S.D.A.  
Dr. T. E. Hienton, Farm Electrification Res. Lab., Agr. Eng. Res. Div., U.S.D.A.  
Dr. H. F. Miller, Chief, Harvesting and Farm Processing Br., Agr. Eng. Res. Div., U.S.D.A.  
Mr. A. N. Halweg, Admin. Officer, Agr. Eng. Res. Division, U.S.D.A.  
Mr. C. F. Rainwater, Head, Cotton Insects Section, Ent. Res. Division, U.S.D.A.  
Dr. S. E. Jones, Chief, Field Crops Insects and Bee Culture Res. Br., Ent. Res. Div., U.S.D.A.

Farm Economics Research Division  
September 22, P.M., 1958, Beltsville, Md.

Dr. Carl P. Heisig, Director, Farm Econ. Res. Div., U.S.D.A.  
Mr. Max M. Tharp, Head, Southeastern Agr. Sec., Farm Econ. Res. Div., U.S.D.A.  
Mr. E. L. Langsford, Head, South Central Agr. Sec., Farm Econ. Res. Div., U.S.D.A.  
Mr. C. F. Rainwater, Head, Cotton Insects Section, Ent. Res. Div., U.S.D.A.

Entomology Research Division  
September 23, 1958, Beltsville, Md.

Dr. S. E. Jones, Chief, Field Crops Insects and Bee Culture Research Branch, Ent. Res. Div., U.S.D.A.  
Mr. R. L. Walker, Asst. to Chief, Field Crops Insects and Bee Culture Res. Br., Ent. Res. Div., U.S.D.A.  
Mr. W. B. Cartwright, Cereal and Forage Insects Section, Ent. Res. Div., U.S.D.A.  
Dr. S. R. Dutky, Insect Pathologist, Insect Pathology Laboratory, Ent. Res. Div., U.S.D.A.  
Dr. W. E. Robbins, Insect Physiologist, Insect Physiology Lab., Ent. Res. Div., U.S.D.A.  
Mr. G. J. Haeussler, Asst. Director, Ent. Res. Div., U.S.D.A.  
Mr. C. F. Rainwater, Head, Cotton Insects Section, Ent. Res. Div., U.S.D.A.  
Mr. S. A. Hall, Director, Pesticide Chemicals Res. Labs., Ent. Res. Div., U.S.D.A.  
Dr. P. W. Oman, Director, Insect Identification & Parasite Introduction Labs., Ent. Res. Div., U.S.D.A.



Crops Research and Soil and Water Conservation Divisions  
September 24, 1958, Beltsville, Md.

Dr. M. W. Parker, Director, Crops Research Division, U.S.D.A.  
Dr. H. D. Barker, Chief, Cotton, Cordage and Other Fiber Crops  
Branch, Crops Res. Div., U.S.D.A.  
Dr. Hardy Tharp, Head, Physiology Section of Cotton Research Br.,  
Crops Res. Div., U.S.D.A.  
Dr. W. H. Alloway, Assistant Director, Soil and Water Cons. Res.  
Div., U.S.D.A.  
Mr. W. B. Cartwright, Cereal and Forage Insects Section, Ent. Res.  
Div., U.S.D.A.  
Dr. S. E. Jones, Chief, Field Crops Insects and Bee Culture Res.  
Br., Ent. Res. Div., U.S.D.A.  
Mr. C. F. Rainwater, Head, Cotton Insects Section, Ent. Res. Div.,  
U.S.D.A.

Texas Agricultural Experiment Station  
September 29, 1958, College Station, Texas

Dr. R. D. Lewis, Director, Texas Agr. Exp. Station  
Dr. J. C. Gaines, Head, Dept. of Entomology, Texas A & M College  
Dr. P. L. Adkisson, Assoc. Prof., Dept. of Entomology, Texas A & M  
College  
Dr. T. B. Davich, Cotton Insects Section, Ent. Res. Div., U.S.D.A.  
Mr. Price Hobgood, Head, Dept. of Agr. Eng., Texas A & M  
Mr. J. P. Hollingsworth, Project Leader, Farm Elec. Res. Lab., Agr.  
Eng. Res. Div., U.S.D.A.  
Mr. A. L. Scales, Entomologist, Ent. Div., U.S.D.A.  
Mr. Robert Foote, Chemist, Ent. Res. Div., U.S.D.A.  
Dr. Erma S. Vanderzant, Chemist, Ent. Res. Div., U.S.D.A.  
Mr. T. C. Cartwright, Dept. of Genetics, Texas Agr. Exp. Station  
Dr. C. M. Lyman, Dept. of Biochemistry & Nutrition, Texas A & M  
College  
Dr. R. L. Hanna, Assoc. Prof., Dept. of Entomology, Texas A & M  
College  
Mr. C. F. Garner, Asst. Ext. Entomologist, Texas Agr. Expt. Station  
Mr. B. G. Hightower, Asst. Prof., Dept. of Entomology, Texas A & M  
College  
Dr. D. A. Lindquist, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. J. R. Brazzel, Assoc. Prof., Dept. of Ent., Texas A & M Coll.  
Dr. J. P. Hacskeylo, Plant Physiologist, Crops Res. Div., U.S.D.A.  
Mr. W. C. Hall, Head, Dept. of Plant Physiology and Pathology,  
Texas A & M Coll.  
Dr. D. F. Martin, Head, Pink Bollworm Section, Ent. Res. Div., U.S.D.A.  
Mr. George Chance, Farmer, Bryan, Texas  
Mr. R. H. Rogers, Agricultural Economist, Farm Economics Res. Div.,  
U.S.D.A.  
Mr. L. H. Wilkes, Agricultural Engineering Dept., Texas A & M Coll.  
Mr. C. B. Godbey, Head Dept. of Genetics, Texas A & M Coll.



Louisiana Agricultural Experiment Station  
October 1, 1958, Baton Rouge, Louisiana

Dr. C. W. Upp, Director, Louisiana Agr. Expt. Station  
Dr. J. J. Mikell, Asst. Director, La. Agr. Expt. Station  
Dr. L. D. Newsom, Head, Entomology Research, La. State Univ.  
Dr. John S. Roussel, Prof. of Entomology, La. State Univ.  
Mr. Bill Bolton, Agricultural Economist, Farm Econ. Res. Div., U.S.D.A.  
Dr. Murray Blum, Asst. Prof., Entomology, La. State Univ.  
Dr. W. K. Porter, Jr., Assoc. Plant Pathologist, La. State Univ.  
Mr. C. H. Thomas, Assoc. Prof., Agr. Engineering, La. State Univ.  
Mr. M. L. Burks, Jr., Chemist, Ent. Res. Div., U.S.D.A.  
Dr. N. W. Earle, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. E. N. Lambremont, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. A. D. Oliver, Asst. Entomologist, La. State Univ.  
Mr. R. C. Gaines, Entomologist, Ent. Res. Div., U.S.D.A.

Delta Pineland Company  
October 2, 1958, Scott, Mississippi

Dr. C. R. Sayre, President, Delta Pineland Co.  
Mr. E. C. Ewing, Sr., Plant Breeder, Delta Pineland Co.  
Dr. W. W. Bradford, Agronomist, Delta Pineland Co.  
Dr. Morris Blocker, Entomologist, Delta Pineland Co.

Mississippi Agricultural Experiment Station  
October 3, 1958, Stoneville, Mississippi

Dr. W. L. Giles, Superintendent, Delta Branch Mississippi Agr.  
Expt. Station  
Dr. Ross E. Hutchins, Head, Entomology Dept., Miss. State College  
Dr. M. E. Merkl, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. T. R. Pfrimmer, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. A. L. Hamner, Entomologist, Miss. Agr. Expt. Station  
Mr. O. B. Wooten, Engineer, Miss. Agr. Expt. Station  
Mr. G. L. Smith, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. R. E. Furr, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. E. P. Lloyd, Entomologist, Ent. Res. Div., U.S.D.A.  
Dr. G. B. Crowe, Agricultural Economist, Ent. Res. Div., U.S.D.A.  
Mr. R. F. Colwick, Agr. Engineer, Agr. Eng. Res. Div., U.S.D.A.  
Dr. L. H. Moseley, District Agent, Ext. Service, Miss. Agr. Exp. Sta.

Alabama Agricultural Experiment Station  
October 6, 1958, Auburn, Alabama

Dr. E. V. Smith, Dean and Director, Ala. Agr. Expt. Station  
Dr. C. T. Wilson, Assoc. Director, Ala. Agr. Expt. Station  
Dr. C. F. Simmons, Asst. Director, Ala. Agr. Expt. Station  
Dr. F. S. Arant, Head, Dept. Zoology-Entomology, Ala. Polytech. Inst.  
Mr. W. A. Ruffin, Extension Entomologist, Ala. Agr. Expt. Station  
Mr. J. W. Rawson, Asst. Entomologist, Ala. Agr. Exp. Station  
Mr. W. H. Grimes, Ext. Survey Entomologist, Ala. Agr. Expt. Station  
Dr. D. G. Sturkie, Professor and Agronomist, Ala. Polytech. Inst.  
Mr. L. J. Chapman, Asst. in Agronomy, Ala. Polytech. Inst.  
Dr. B. W. Arthur, Asst. Entomologist, Ala. Polytech. Inst.



Georgia Agricultural Experiment Station

October 7, 1958, Experiment, Georgia

Mr. K. Treanor, Director, Branch Stations, Ga. Agr. Expt. Sta.  
Dr. C. M. Beckham, Chairman, Div. of Entomology, Univ. of Ga.,  
Experiment, Ga.  
Dr. J. B. Weaver, Jr., Asst. Prof., Cotton Breeding, Univ. of Ga.,  
Athens  
Mr. B. S. Hawkins, Agronomist, Crops Res. Div., U.S.D.A.  
Mr. R. W. Morgan, Asst. Entomologist, Ga. Agr. Expt. Sta., Tifton  
Dr. H. H. Tippins, Assoc. Entomologist, Ga. Agr. Expt. Sta., Tifton  
Dr. J. J. Paul, Asst. Prof. of Entomology, Univ. of Ga., Athens  
Mr. J. G. Jenkins, Agronomist, Ga. Agr. Expt. Sta., Tifton  
Mr. S. A. Parham, Agronomist, Ga. Agr. Expt. Sta., Tifton  
Mr. W. W. Sell, Ext. Agronomist, Ga. Agr. Expt. Sta., Athens  
Dr. C. R. Jordan, Ext. Entomologist, Ga. Agr. Expt. Sta., Athens  
Mr. J. L. Butler, Agricultural Engineer, Ga. Agr. Expt. Sta., Experiment

North Carolina Agricultural Experiment Station

October 27, 1958, Raleigh, North Carolina

Dr. R. L. Lavvorn, Director, N. C. Agr. Expt. Station  
Dr. Clyde Smith, Head, Dept. of Entomology, N. C. State College  
Dr. W. J. Mistic, Jr., Asst. Prof., Dept. of Entomology, N. C.  
State College  
Mr. George D. Jones, Extension Entomologist, N. C. Agr. Expt. Sta.  
Dr. R. T. Gast, Asst. Prof., Dept. of Entomology, N. C. State Coll.  
Dr. S. G. Stephens, Prof., Dept. of Genetics, N. C. State Coll.  
Dr. J. R. Mauney, Plant Physiologist, Crops Res. Div., U.S.D.A.  
Dr. P. A. Miller, Field Crops, Cotton Breeding, N. C. Agr. Expt. Sta.  
Dr. R. E. Fye, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. Wallace Giles, Head, Agr. Engineering Dept., N. C. State Coll.  
Dr. Robinson, Head, Dept. of Genetics, N. C. State Coll.  
Mr. Wm. Splinter, Agr. Engineering Dept., N. C. State Coll.  
Mr. John Kramer, Dept. of Entomology, N. C. State Coll.

Coker Pedigreed Seed Company

October 28, 1958, Hartsville, South Carolina

Dr. Robert R. Coker, President, Coker Pedigreed Seed Co.  
Dr. J. W. Neely, Vice-President for Research, Coker Pedigreed Seed Co.  
Mr. J. W. Talbert, Vice-President for Sales, Coker Pedigreed Seed Co.

South Carolina Agricultural Experiment Station

October 29, 1958, Florence, South Carolina

Dr. O. B. Garrison, Director of S. C. Expt. Station, Clemson, S. C.  
Dr. M. D. Farrar, Dean of Agriculture, S. C. State Coll., Clemson  
Dr. J. H. Cochran, Head, Dept. of Entomology, S. C. State Coll.,  
Clemson  
Mr. Norman Allen, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. James M. Stanley, Agr. Eng. Res. Div., U.S.D.A.



Mr. David C. Harrell, Agronomist, S. C. Agr. Expt. Station  
Mr. John B. Pitner, Supt., Pee Dee Expt. Station, S. C. Agr. Expt. Sta.  
Mr. Charles A. Thomas, Entomologist, Edisto Station, S. C. Agr. Expt. Sta.  
Mr. William A. Balk, Assoc. Agric. Engineer, Edisto Station, S. C. Agr. Expt. Sta.  
Mr. John K. Reed, Assoc. Ent., S. C. State College, Clemson  
Dr. R. E. Fye, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. Bernard L. Owen, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. A. R. Hopkins, Entomologist, Ent. Res. Div., U.S.D.A.  
Mr. William W. McMillan, Asst. Entomologist, S. C. Agr. Expt. Sta.  
Mr. Charles P. Butler, Agricultural Economist, Farm Econ. Res. Div., U.S.D.A.  
Dr. Robert R. Coker, President, Coker Pedigreed Seed Co., Hartsville, S.C.

Oklahoma Agricultural Experiment Station

November 3, 1958, Stillwater, Oklahoma

Dr. L. E. Hawkins, Dean and Director, OSU  
Dr. D. E. Howell, Head, Entomology Department, OSU  
Mr. E. W. Schraeder, Head, Agri. Engineering Dept., OSU  
Mr. K. D. Arbuthnot, Entomology, ARS and OSU  
Mr. W. F. Lagrone, Agricultural Econ., ARS  
Mr. C. L. Leinweber, Agronomy-Botany, ARS  
Dr. D. E. Bryan, Entomology Department, OSU

Arkansas Agricultural Experiment Station

November 4, 1958, Fayetteville, Arkansas

Dr. John White, Assistant Director  
Dr. C. Lincoln, Head, Department of Entomology  
Mr. Gordon Barnes, Extension Entomologist  
Mr. W. P. Boyer, Survey Entomologist  
Mr. Robert C. Hunter, Junior Entomologist  
Mr. Leon Moore, Research Assistant  
Mr. Louis Bariala, Graduate Assistant  
Mr. J. Hodge Black, Research Assistant  
Mr. Kermit Stevenson, Agricultural Engineering  
Dr. Brad Waddle, Plant Breeder

Production and Marketing Division, National Cotton Council

November 7, 1958, Memphis, Tennessee

Mr. Claude L. Welch, Director, Production and Marketing Division  
Mr. Leonard Lett, Agronomist  
Mr. Vernon P. Moore, Marketing  
Mr. J. K. Jones, Agricultural Engineer  
Dr. Burt Johnson, Research Advisor  
Mr. C. S. Buck, Jr., Assistant to Executive Vice-President  
George Townsend, Agricultural Economist





